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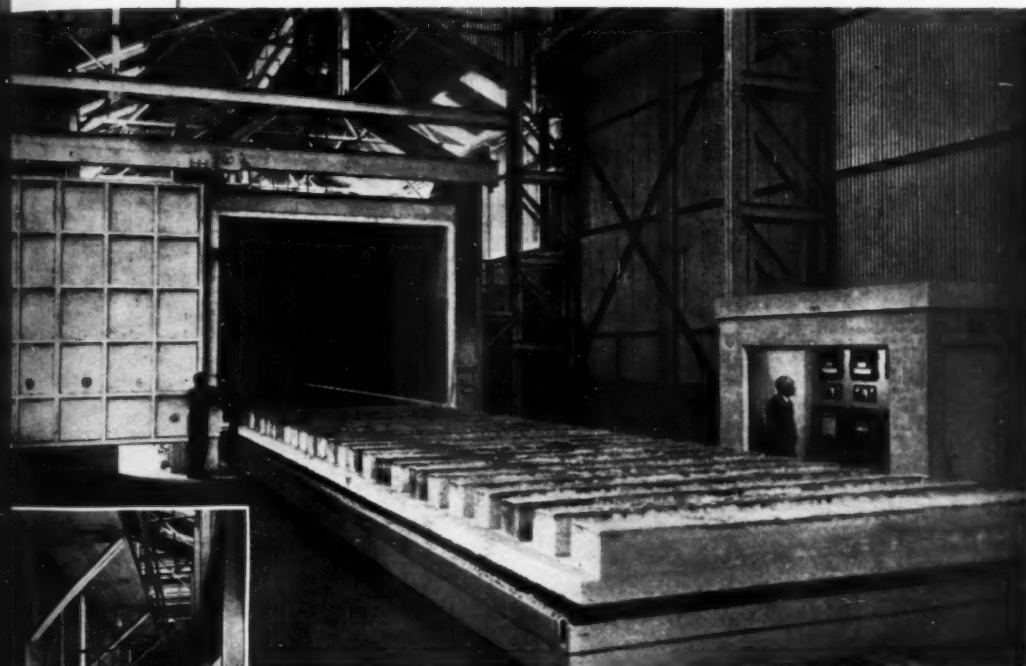
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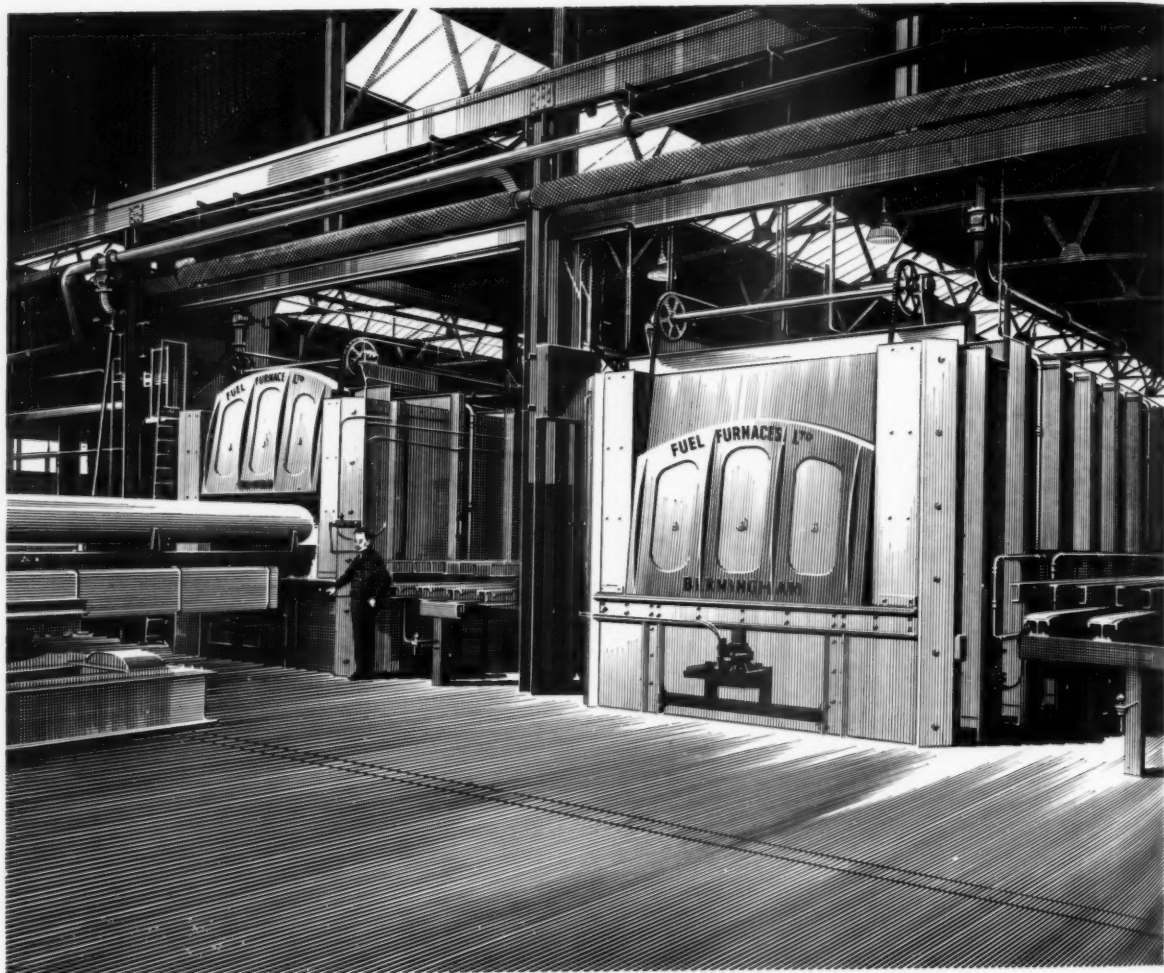
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# METALLURGIA

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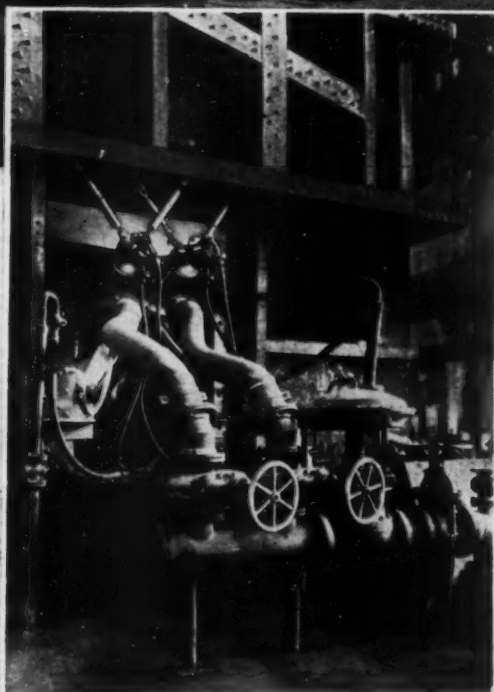
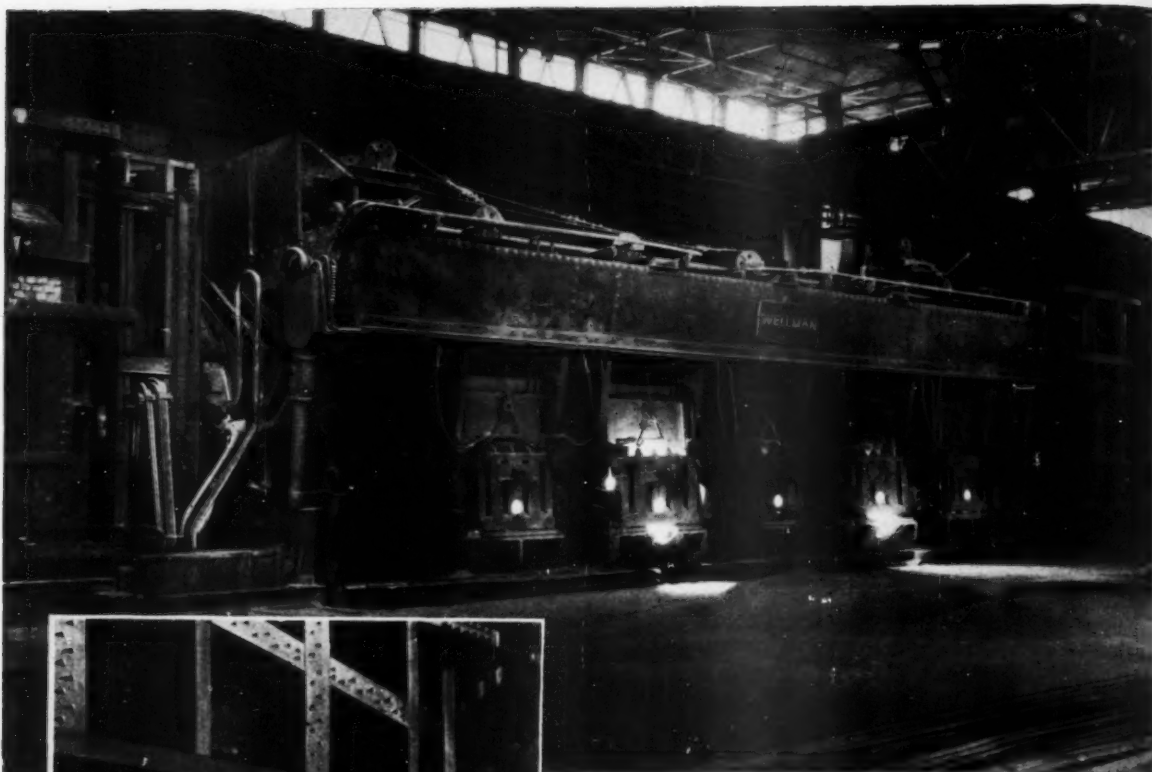
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# METALLURGIA

THE BRITISH JOURNAL OF METALS  
INCORPORATING THE "METALLURGICAL ENGINEER"

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## Research and the Small Firm

TEN years ago Sondes Place Research Institute was founded to provide industry with facilities for confidential research and development in the fields of applied chemistry, chemical engineering and mechanical engineering, and in a recent issue of *Report*, which is published by the Institute from time to time, the functions of the sponsored research institute are studied against the background of industrial research in general.

Most of the applied research in this country is carried out in the laboratories of the larger industrial firms and public corporations. Apart from these organisations, there are three main agencies for applied research in the U.K. The first of these—the universities and technical colleges—is probably the least important as regards applied research, since these institutions are more concerned, quite rightly, with fundamental research for its own sake and as a means of training scientists. Nevertheless, they are today showing a greater realisation than ever of the importance of maintaining contact with industry, in the extension of which the practice of firms in employing university teachers as part-time consultants is playing an important part. The second group of applied research laboratories are those of the defence ministries, which are primarily concerned with the needs of the services, and which may be of help to industry on an *ad hoc* basis, but are not available for carrying out extensive confidential investigations. Finally, there are the organisations with which the Department of Scientific and Industrial Research is concerned. Among these are fourteen research establishments—including the National Physical Laboratory, the Chemical Research Laboratory and the Mechanical Engineering Research Laboratory—mainly concerned with Government-financed research of general value to the community, the results being freely available to all. Only to a limited extent is confidential work undertaken, and it is rare indeed for a major research to be conducted on this basis. D.S.I.R. is also interested in the forty-seven research associations in the country, each dealing with the problems of a particular industry. The function of a research association is to carry out co-operative research for the benefit of its members as a whole; it follows, therefore, that the undertaking of confidential work for individual members is at variance with the objects of the association.

The organisations considered so far are mainly concerned with research for the benefit of industry as a whole, or of groups of firms, as in the case of the research associations. Research on behalf of a particular firm is mainly carried out in its own laboratories, a procedure which is satisfactory enough in the case of the large firm, but which is not feasible in the case of many small units. Membership of a research association provides the answer to the question of technical assistance for some small firms, and in other cases satisfaction is obtained by employing a consultant. Neither of these

meets the need of the small firm completely. There still remains the problem of the investigation designed to develop a new process or a new product, from which the firm hopes to gain financial reward in competition with similar firms. The research association cannot undertake this work for the reasons given above, and the consultant is mainly concerned with applying his highly specialised knowledge to the solution of practical problems, rather than with creating new knowledge by research.

It was against such a background that the Fulmer Research Institute, specialising in metallurgy—especially non-ferrous metallurgy—and related chemical fields, was founded in 1947, and the Sondes Place organisation a year later. These two institutes exist to provide facilities for undertaking experimental work of a confidential nature under contract. Both are independent, in the sense that they have to pay their way without government grants or subsidies, and both have expanded steadily since their foundation. Nevertheless, they remain the only two wholly British sponsored research institutes. In the U.S., on the other hand, progress in this field during the past forty-five years has been spectacular, the nine major institutes having an annual research expenditure exceeding \$50 million.

In considering the reasons for this difference, it must not be overlooked that there are no research associations in the U.S., so that most of the work which in this country would be done by these bodies has to be undertaken by sponsored research institutes. In the main, the greater success of sponsored research in America probably stems from the fact that the value of research is more widely appreciated there. Nevertheless, this appreciation seems to be confined to the larger firms on both sides of the Atlantic.

In view of the fact that sponsored research seems to have much to offer to the small firm, whose problems are too infrequent to warrant the expense of setting up its own laboratory, this failure to take advantage of the facilities for it is, to say the least, surprising. It is further evidence in support of the charge that the majority of small firms are not research-minded. Dare one suggest that the two things go hand-in-hand—that they are small firms because they are not research-minded. Certainly many small firms do not seek advice on their problems even when it is available free of charge through D.S.I.R. establishments and official information services. There is evidently need for an enlightenment campaign to demonstrate to small firms that research, or at least technical advice, can have a monetary value for them.

Quite apart from financial considerations, acceptance of sponsored research by the small firm may be hindered by fears that in some way the results of the investigation may reach competitors, and that even their own old-established practice will no longer remain secret. Although these fears are quite groundless, they are not easily quashed in firms where "trade secrets" are regarded as the company's most important assets.

## Galvanizing Conference

**G**ALVANIZING may be an old and traditional industry but its present leaders are young and progressive in their outlook, as was clearly shown at the Fifth International Galvanizers Conference held at Scheveningen, Holland, and at Knokke-le-Zoute, Belgium from 22nd-27th June. Attendance was larger than ever before and over 350 delegates from 22 countries including Russia, Japan, and the United States of America, were welcomed by the first President of the European General Galvanizers Association, Dr. H. Bablik, who in his opening address, referred to the new spirit of co-operation which had brought together so many competitors to study and discuss the practical, technical and human problems of their long-established industry. He stressed the importance of using technical knowledge and progress for the service of mankind rather than for its enslavement.

This challenging address was the prelude to nine technical sessions at which thirty-three main and subsidiary papers on all aspects of galvanizing were presented by authors from Austria, Belgium, Canada, France, Germany, Great Britain, Holland, Italy, Switzerland and the United States of America. The Chairman of the British Hot Dip Galvanizers Association, Mr. E. M. Wilson of Henry Hope and Sons, Ltd., together with leaders of the Belgian and German industries, outlined in the first session the contribution of galvanizing to human and technical progress.

Another session was devoted to three papers on the "Preparation of Material for Galvanizing" and later the results of an extensive survey made by the British Non-Ferrous Metals Research Association on the relative merits of wet and dry galvanizing were given. Modern methods of galvanizing bath heating were described in detail; developments in oil heating were reviewed by Mr. J. G. C. Pope of the Shell Petroleum Company, and the top heating of galvanizing baths by Dr. Haarmann of Germany. Other papers dealt with electrical resistance heating and experience with a small induction heated bath used for general galvanizing.

In an important paper comparing the Cook-Norteman and Sendzimir processes, Dr. Bablik examined some of the fundamental problems associated with continuous strip galvanizing, and reported that there are now some 55 lines in operation in the Western World—33 in the United States and 14 in Western Europe. Interesting contributions to the discussion of this paper were made by Dr. Cook and Mr. Sendzimir. Other aspects of specialist galvanizing were covered in papers from France, Holland and Italy. Subjects of particular importance to all galvanizers, such as the effect of impurities in, and additions to, the galvanizing bath, non-destructive testing of galvanized coatings, and the effect of steel composition on the galvanized coatings, were discussed in detail, and delegates from the U.S.A., Holland and the United Kingdom presented papers on the importance of, and possible improvements in, materials handling in galvanizing.

Mr. R. Lewis Stubbs, Director of the Zinc Development Association spoke at the conclusion of the conference of the steady growth of galvanizing in recent years. It had taken some 410,000 tons of zinc in Western Europe in 1957, a rise of nearly 10% since 1955. This record consumption compares with 320,000 metric tons in the United States last year, and surpasses even the

highest U.S. figure (1955). Mr. Stubbs stressed the huge opportunities still awaiting the galvanizing industry; the new relationship between the cost of labour and of raw materials made it imperative that effective methods of rust prevention involving little or no maintenance should be used wherever possible. As usual, the edited proceedings of the Conference, including all the discussion the papers presented, will be published later in the year.

## Geigy Bicentenary

**A**T a reception to mark the bicentenary of the Geigy organisation, a toast to the company was drunk, most appropriately, in Kirsch made from cherries grown on the Geigy experimental farm, near Basle, for it was at Basle in 1758 that Johann Rudolf Geigy set up as a merchant of dyes and pharmaceutical drugs. From this modest business has grown a network of some fifty companies, operating in many countries, and linked by ties of varying closeness to the parent company in Basle, J. R. Geigy, S.A. Throughout these two hundred years, the firm has borne the name Geigy, and there is still a direct descendant of the founder on the Board.

It was in the dyeing industry that the name of Geigy was best known up to World War II, when the discovery of DDT insecticides in the Basle laboratories spread its fame throughout the world. To-day, research and development have widened the scope of Geigy's interests to include products for purposes as diverse as the production of nylon, the relief of rheumatism, and the lubrication of aircraft jet engines. The activities of Geigy in each country vary according to local facilities and needs. Not all Geigy products are marketed in every country, and some factories outside Switzerland make products which are not made by the parent company. Thus, Geigy in Britain have specialised in plastic chemicals to a greater extent than Geigy in Switzerland.

The Geigy organisation's products are many and various, and include dyestuffs, textile chemicals, pigmentary colours, pesticides, plastics chemicals, pharmaceuticals and general chemicals. In the last-named group are to be found a wide range of products for special application in many industries. These include chelating (sequestering) and wetting agents used in the cleaning of metals, the prevention and control of corrosion, and electroplating; water treatment for scale prevention; and photographic chemicals. Investigations now in progress are also focussing attention on organic chemicals for metal treatment, and for use in the production of rare metals now coming into use to meet the special needs of nuclear energy production. A Geigy product is now used in the separation of rare earth elements.

The company believes that the future is bright for the chemical industry, with its ability to transmute one substance into another, and so to overcome shortages of various materials. Yet the very success which has been achieved in science and technology is not without its dangers, unless the sense of responsibility keeps pace. As a world-wide enterprise with two hundred years of history which has played a part—often a creative part—in the life of the chemical industry from its inception, Geigy is fully alive to these issues. As the bicentenary booklet has it: "Knowledge, a sense of responsibility, courage, and the determined efforts of thousands of individuals, these are the true foundations on which Geigy must build for the future."

# Stirring in Steel Production

## Mechanical and Inductive Stirring in the Arc Furnace

By Arne Faerden

*Following a brief survey of developments in the production of electric steels, and in the most commonly used methods of stirring, the author deals fully with the mechanical and inductive methods. Reference is also made to blowing gases or metallic vapours through the melt, reladling, and rotating the furnace. The results obtained during experience with mechanical stirring are given, and the relative merits of the mechanical and inductive methods discussed.*

THE first serious attempts at using electricity in the melting of steel and other metals were made during the nineteenth century, and the first electric arc furnaces of the Héroult type came into use shortly after the turn of the century. The capacity of these furnaces increased from 4-5 metric tons in about 1906, to approximately 10 metric tons in 1910,<sup>1,2</sup> but it was only during the first World War that the development of the electric arc furnace began to make rapid progress; at that time a number of furnaces with a capacity of 25 metric tons were built in the U.S.A.

In most countries this development came to a standstill in the years between the wars, but the second World War again provided an impetus for rapid expansion—an expansion which has continued, though to a lesser degree. During the second World War, furnaces with capacities up to 100 metric tons were commissioned in the U.S.A., and this figure has continued to increase, so that the largest electric arc furnace in use today has a capacity of approximately 180 metric tons. By way of comparison, the largest induction furnaces now available have a capacity of 12 metric tons.<sup>3,4</sup>

Surveys of the production of Siemens-Martin, Bessemer and electric steel for 1932 and 1952, show that the production of electric steel, in all the more important steel-producing countries, increased considerably during these twenty years. This increase is true, both for the actual quantity produced and for the output of electric steel expressed as a percentage of the entire steel production of the country (see Table I). In Norway, steel production amounted to approximately 60,000 metric tons in 1932, increasing to some 100,000 metric tons in 1952—almost all of which was produced in electric arc furnaces.

Movement within the bath of molten steel, due to electrodynamic causes is, to all practical intents, negligible, according to Dreyfus.<sup>5</sup> Thus, the increase in furnace size has introduced a new problem—to achieve satisfactory mixing in the metal bath and a satisfactory speed of reaction between the bath and the slag layer. The problem has become of general interest because of the considerable increase in the production of electric steel.

Stirring does not, of course, present any problems in the case of steel produced in converters; nor for Siemens-Martin steel, as this is generally tapped immediately on completion of the decarburisation period.<sup>7</sup> It may also be noted that satisfactory mixing is achieved in all types of induction furnace. It must therefore be understood

TABLE I.—PRODUCTION OF ELECTRIC STEEL<sup>8</sup>

Country	Annual Production in Million Metric Tons		Production of Electric Furnace Steel as Percentage of Total Steel Production	
	1932	1952	1932	1952
U.S.A. ..	0.3	6.8	1.8	7.3
U.K. ..	0.1	1.0	1.0	5.7
France ..	0.2	0.9	2.8	7.7
Germany ..	0.1	0.6	2.0	3.3
Italy ..	0.3	1.6	17.0	46.0
Sweden ..	0.1	0.7	23.0	41.0

that wherever stirring in the production of steel is discussed in the following pages, it refers to stirring in electric arc furnaces, and then only to those cases where refining (deoxidation, desulphurisation, etc.) is carried out in the furnace.

By way of introduction, reference may be made to the fact that stirring is also an important stage in the refining of pig iron. Tigerschild, for instance, has successfully desulphurised pig iron by means of fluid slag, the stirring of the iron being carried out inductively with the aid of a low frequency current. In an analogous process, stirring was effected by blowing nitrogen through the bath. In this connection, mention may also be made of Kalling's process,<sup>8,9</sup> in which desulphurisation is achieved by treating the pig iron with solid pulverised lime in a rotating furnace. The speed of desulphurisation here depends on several factors, including the speed of rotation of the furnace, or, in other words, the rate of stirring.

### Methods of Stirring

Research carried out in recent years clearly demonstrates that the properties of a steel—its quality—are not determined solely by its content of carbon, manganese, silicon, nickel, chromium, etc., but also, and materially, by the content and distribution of elements whose amounts are measured in terms of thousandths of one per cent. It is further well known that slight variations in these minor constituents, e.g., in the amounts of oxygen, sulphur, aluminium, nitrogen, etc., can suffice to bring about a radical change in the properties of a steel.

An analysis of the many factors involved in the production of high quality steel—one of which is having the amounts of minor constituents under control—shows that these factors are closely bound up with that of stirring during the refining period, because stirring affects both the melt in the steel bath and the speed of reaction between the molten steel and the slag layer.



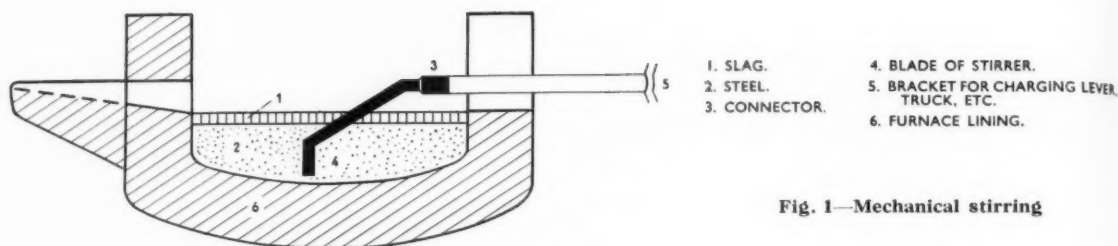


Fig. 1—Mechanical stirring

It is apparent from the foregoing that stirring during the refining period is one of the most important factors in the production of a steel of high quality, and it would therefore be natural to assume that this point has been exhaustively treated in technical literature. However, apart from the literature on inductive stirring, referred to later, the subject has received scant notice.

The following discussion is concerned mainly with methods where stirring is carried out in the actual furnace; thus the Perrin method<sup>10</sup> and an analogous method mentioned by Sundström<sup>13</sup> and described as "slag washing," are not considered in detail.

#### Mechanical Stirring

The term "mechanical stirring" may be used to describe stirring by means of a rake which is moved to and fro in the steel/slag bath by hand or motor power. To the author's knowledge, this method has not been thoroughly investigated, but has only received brief mention in a number of articles.

A hand-powered rake is mentioned by, e.g., Bigge,<sup>11</sup> who states that, during the production of 18-4-1 high-speed steel in a furnace of 7 metric ton capacity, the melt is normally stirred thoroughly eight times, this stirring beginning just before the charge is melted and continuing until just before it is tapped. In the U.S.A., larger furnaces, where it is very difficult to reach every part of the melt, are usually equipped with two doors set at an angle of 90°; these doors also simplify the deslagging process.<sup>12</sup> Manual stirring is also discussed by Sundström,<sup>13</sup> who states: "Long experience at Bofors demonstrates that good results are obtained by manual stirring."

This method of stirring is undoubtedly effective when used with furnaces of about 10 metric tons capacity, possibly even for capacities of up to 20 metric tons. This conclusion is based partly on Nilsson's<sup>12</sup> statement that in the U.S.A., batches which do not exceed 7-8 tons in weight are preferred when producing high-speed steel, partly on the fact that inductive stirring has been installed in a 10-ton furnace, and partly on Patterson's<sup>14</sup> experience with manual stirring, which shows that this method is effective in the case of 10-ton furnaces, but not in the case of 20-ton furnaces. It appears from the discussion of Patterson's article<sup>14</sup>, however, that one may assume that manually operated stirring devices can be employed in 20-ton furnaces.

In the case of larger furnaces, manual stirring will certainly increase the speed of reaction between the slag and the metal, but the actual mixing will hardly be satisfactory. A serious disadvantage of this method—even in the case of smaller furnaces—is that it entails extremely strenuous work, whose success depends largely on the skill, endurance and reliability of the operator.

The motor-powered rake is a natural development of

manually powered stirring, which can be used in both large and small furnaces. The principle of this method of stirring is demonstrated in Fig. 1. In discussing it, Tigerschiöld<sup>15</sup> states that "they (the Bethlehem Steel Co.) had constructed a powerful rake which was fixed to the charging machine; by moving this to and fro, violent agitation within the bath could be achieved. The rake is also used for deslagging." From the discussion on Patterson's paper, it is evident that mechanical stirring is generally regarded as satisfactory in use.

#### Inductive Stirring

According to Rohland,<sup>16</sup> Ferranti and Stassano, two of the pioneers in the making of electric steel, were the first to consider employing electrodynamic forces to produce agitation in the steel bath. Hiorth<sup>1\*</sup> must also be mentioned in this connection, for in 1906, he secured a patent for a type of furnace which was a combination of induction furnace and Héroult furnace.<sup>17</sup>

Work on inductive stirring in electric arc furnaces started in earnest in the mid-1930s—partly in Germany, where the second World War presumably put a stop to further development, and partly in Sweden, where equipment suitable for inductive stirring has been successfully produced.

In Germany, only an experimental furnace was built, with a power rating of 1,200 kVA., of which up to 750 kVA. was used on induction. These figures are taken from the rather scanty data supplied by Rohland.<sup>16</sup> It appears that satisfactory stirring was obtained; desulphurisation of pig iron was, for instance, achieved five or six times as fast with stirring as without.

In Sweden, development of the inductive stirrer commenced in 1936, when Dreyfus studied the problem of whether a hot melt could be stirred by means of electricity.<sup>18</sup> The method was tried out in 1939 at Surahammars Bruk A.B., with a 15-ton furnace. However, owing to the construction of the furnace, the stirrer had to be placed within the furnace shell, with the result that it was ruined after a few months.

In 1947 an inductive stirrer was commissioned by Uddeholm A.B. on a 15-ton furnace, and shortly afterwards Surahammars Bruk installed one for a 10-ton furnace. In 1949, Dreyfus<sup>6</sup>, Nilsson<sup>12</sup> and Fornander<sup>19</sup> published papers dealing with the principles of this method, and the experience gained during eighteen months' operation. During the period 1949-1954, six induction stirrers have been installed by Swedish plants,<sup>20</sup> and installations have also been made in Spain, France and Belgium. In the U.S.A., an inductive stirrer was installed by the Timken Roller Bearing Company on one of their 90-ton furnaces in 1952.<sup>21, 22</sup>

The stirrer, operating on two-phases, is placed under the non-magnetic base plate of the furnace. The electric

\* In 1909-10, Albert Hiorth founded the first Norwegian electric furnace steel works, A/S Jossingfjord Mfg. Co., Hellern, Jossingfjord.<sup>2</sup>



currents in the two phases induce electric current paths in the liquid steel bath. At the same time the two phases generate a moving magnetic field which reacts upon the steel; these fields produce forces parallel to the furnace bottom. In other words, the principle is the same as that of an induction motor, the stirrer acting as stator and the steel bath as rotor (see Fig. 2).

The following summary of experience with inductive stirrers, is based mainly on papers by Nilsson,<sup>6, 12, 23</sup> Fornander,<sup>19, 24</sup> and Walther.<sup>22</sup>

During the melting and the decarburisation stages bath motion is not normally affected noticeably by the stirrer. It has been stated that the stirrer has given good results in cases where an especially low carbon content was desired, but this result can be achieved four times as fast by blowing through with oxygen than by ore additions and inductive stirring.<sup>25</sup>

Complete and thorough mixing is achieved during the refining stage, so that both temperature and composition are uniform throughout the bath. It has also been claimed that the time necessary for refining can be reduced, as inductive stirring promotes quicker deoxidation and desulphurisation. It is estimated that 20-30 minutes—in some cases even as much as an hour—can be saved on each heat. Björgerstam<sup>26</sup> refutes such a saving of time for the smaller types of furnace, and the possibility of increased production resulting from it. Nor does Leigh<sup>27</sup> mention it in his survey of experience with the 90-ton furnace installed at the Timken Roller Bearing Company. Any saving of time which may be effected during the refining stage undoubtedly depends on so many factors peculiar to the individual steelworks that any further discussion would not come within the scope of this article.

Deslagging is very much easier when a stirrer is used, as the motion of the bath carries the slag towards the furnace door: this is of special importance in those processes which require two or more slags. Christensen and Nilsson<sup>28</sup> confirm the claim that deslagging is made easier by the use of a stirrer. By standards set during studies of labour physiology, the work of deslagging without a stirrer is described as "heavy," while the same work with a stirrer is described as "moderately heavy."

Among the factors affecting the efficiency of stirring is the thickness of the furnace bottom. As will be seen from Fig. 3, the effect is marked, but as far as the author is aware, no operational difficulties due to the thickness of the furnace bottom are discussed in technical literature.

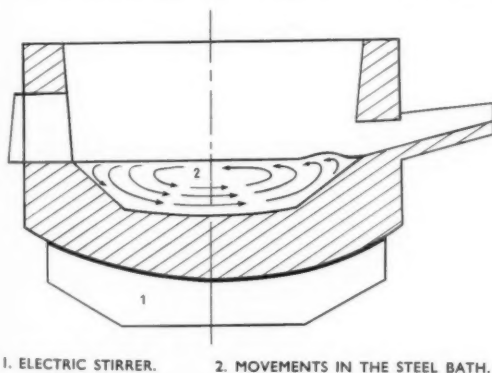


Fig. 2—Inductive stirring: bath motion in the Hagfors furnace.<sup>12</sup>

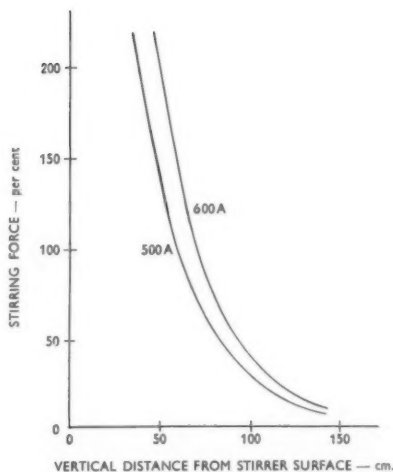


Fig. 3—Effect on stirring power of distance from the surface of the stirrer.

#### Other Methods of Stirring

Stirring by means of blowing gases through the melt—the same principle as that which causes the violent agitation during the decarburising stage—has been discussed by Tigerschiöld,<sup>15</sup> who states that satisfactory stirring is achieved by blowing nitrogen through the bath. The experience of Kennedy<sup>29</sup> with blowing argon through the bath was, not however, entirely satisfactory, as he concludes that this method of stirring— $\frac{1}{2}$  in. tubes with a gas pressure of 2.8 kg./sq. cm.—has too localised an effect.

Tigerschiöld cites another method which is based on generation of gas, namely, gas generated by metallic magnesium when it is dipped into the steel bath. This method, apart from producing powerful agitation, also brings about very satisfactory deoxidation. Kennedy used calcium instead of magnesium, but did not achieve satisfactory mixing. (The size of the furnace is not stated).

E. Spire<sup>32</sup> devised an original method of stirring, in which the steel (or pig iron, as the case may be) is tapped into a ladle which has a porous, heat-resistant plug. A stream of argon is directed through the plug, causing a violent "boiling" in the ladle. It is stated that this method, apart from achieving complete mixing, also gives considerable desulphurisation and lowers the gas content of the bath.

Attempts have also been made to overcome the difficulties in the way of achieving a homogeneous bath by tapping the entire melt, or a part of it, into a ladle, and then pouring the steel back into the furnace (reladling). Kennedy<sup>29</sup> prefers this method to mechanical stirring and to stirring by means of blowing through with gases. The same author<sup>30</sup> also discusses the reladling method with reference to the production of stainless steel. Green<sup>31</sup> also states that he has achieved satisfactory results by the reladling method.

Mention ought, however, to be made of the fact that this procedure requires certain definite pre-conditions, and conditions obtaining at the furnace often render the use of the method difficult. On the other hand, the reladling method has a special advantage, in that by its use it is possible to determine the weight of the heat,

provided that all the steel is discharged into the ladle.

All the methods of stirring mentioned in this section are based on the normal construction of electric arc furnaces, i.e., with three pendent electrodes and a stationary furnace. There are, however, other types of electric arc furnace in which stirring takes place. There are, for instance, some few electric arc furnaces of up to 25 metric ton capacity which are equipped with bottom electrodes: such furnaces are to be found in Sweden and in England.<sup>4</sup> According to Østberg,<sup>33</sup> they have the advantage that considerable electrodynamic stirring is effected by the current passing through the base electrodes.

Revolving furnaces\* have also been constructed, which are able to turn within a given angle in a horizontal plane. The intention of this type of construction is, first and foremost, to achieve better conditions during the melting process, but it can also bring about a certain stirring effect in the bath during the period of refining. However, it is felt that these advantages do not compensate for the increase in capital expenditure and in the cost of maintenance, and it seems unlikely that the use of this type of furnace construction will spread beyond the two or three furnaces now in use in England.<sup>27†</sup>

### Results Obtained by Mechanical Stirring

A mechanical stirrer fixed to the charging lever (Fig. 1) was first commissioned at A/S Strømmens Værksted, in October, 1950, and has since been used continuously. During this period, the stirrer has been operated on furnaces of 20, 30 and 50 metric tons capacity, and the size of the heat has varied from rather less than 10 tons to 60 tons.

After some experience with the device, the following procedure for stirring during the refining stage for such qualities as make a thorough mixing in the steel bath essential, was evolved. After a preliminary deoxidation of the deslagged bath, half of the slag making materials (lime + fluorspar) is added, and, as soon as the addition has become suitably liquid, the electrodes are raised and the stirrer—made of steel—is dipped into the slag two or three times so as to get a protective layer around it. Then the stirrer is lowered to the bottom of the furnace where it is moved to and fro for two to three minutes. The stirrer is then taken out for a short time, so that it may cool off; after which, stirring is resumed for another two or three minutes. Thus the total time of stirring is from four to six minutes. The preliminary test sample is now taken, and the rest of the slag is added. When the result of the analysis has been obtained, the composition is adjusted, and stirring as described above is again carried out.

In the case of more exacting qualities, when it is desired to hasten the speed of reaction between steel and slag, mechanical stirring has been carried out with shorter intervals, e.g., every 20 or 30 minutes, and manual stirring has been carried out in addition.

The results of experience with mechanical stirring can be summarised as follows.

\* The idea of rotating the electric furnace is old; one description is found in "Electrisk Jern- og Stålsmetning" p. 153, where it is stated, concerning Stassano's electric arc furnace dating from about 1910: "The furnace is so constructed that it may be rotated around a central axis which slants at an angle of approximately 20° from the perpendicular, in order to achieve motion and mixing within the bath."

† Since this article was written, it has come to the author's knowledge that the two furnaces of 50 metric tons capacity at A/S Norsk Jernverk, Mo i Rana, are both of the revolving type (30° to either side). For more detailed information, reference may be made to *Iron & Coal Trades Review*, 1955, 171, (4568) 1007.

Stirring is not normally used during either the melting or decarburisation stages. An exception to this arises when melts with an especially low carbon content are to be made. In such cases stirring has been applied during the latter part of the decarburisation stage. No figures are available to show any possible advantages of this, but the impression obtains that stirring at least helps to give more stable results.

Complete mixing is achieved during the refining stage, so that both temperature and composition are uniform throughout the bath. The claim that stirring satisfactorily equalises the temperature is based on the results of two to three temperature readings taken in different parts of the bath, immediately after each other, using a quick-immersion thermocouple. The assertion that a homogeneous bath is obtained through stirring is based: (a) partly on analyses of samples taken from different parts of the furnace immediately after each other (see Table II); (b) partly on a comparison of these analyses with an analysis taken from the ladle, provided that the entire melt is tapped in one ladle and at the same time; and (c) partly on a comparison of the final analyses of samples taken from two, possibly three lades, provided these have been tapped immediately after each other.

TABLE II.—THE EFFECT OF MECHANICAL STIRRING ON MIXING WITHIN THE BATH.

Heat No.	Size of Heat (met. tons)	Sample No.	% Chromium			% Silicon			% Manganese		
			a	b	Difference	a	b	Difference	a	b	Difference
8288	11.5	4	8.4	8.2	0.2	0.08	0.08	0.00	0.13	0.13	0.00
		5	8.4	8.4	0.0	0.08	0.08	0.00	0.18	0.18	0.00
		6	9.2	9.3	0.1	0.18	0.19	0.01	0.19	0.20	0.01
		7	9.1	9.0	0.1	0.25	0.22	0.03	0.22	0.20	0.02
8307	17.1	4	0	0	0.0	0.28	—	—	0.32	0.34	0.02
		5	4.0	4.0	0.0	0.23	0.24	0.01	0.64	0.63	0.01
		6	10.9	10.8	0.1	0.13	0.12	0.01	0.66	0.62	0.04
		7	11.4	11.5	0.1	0.39	0.40	0.01	0.61	0.61	0.00
8320	17.3	4	—	—	—	0.39	0.37	0.02	—	—	—
		5	2.6	2.6	0.0	0.36	0.37	0.01	—	—	—
		6	4.0	4.0	0.0	0.39	0.38	0.01	—	—	—
		7	10.3	10.5	0.2	0.46	—	—	—	—	—
8810	17.6	4	—	—	—	—	—	—	—	—	—
		5	4.5	4.5	0.0	0.41	0.48	0.07	0.64	0.62	0.02
		6	6.4	6.4	0.0	0.21	0.22	0.01	0.68	0.68	0.00
		7	10.8	10.9	0.1	0.43	0.43	0.00	0.68	0.67	0.01
8905	17.8	4	—	—	—	0.68	0.67	0.01	0.53	0.57	0.04
		5	5.6	5.7	0.1	—	0.42	—	0.62	0.61	0.01
		6	5.0	5.0	0.0	0.42	0.40	0.02	0.58	0.58	0.00
		7	8.0	—	—	0.50	0.47	0.03	0.73	0.74	0.01
8872	20.5	4	—	—	—	—	—	—	—	—	—
		5	1.7	1.7	0.0	0.53	0.51	0.02	0.67	0.66	0.01
		6	2.8	2.8	0.0	0.56	—	—	0.67	0.67	0.00
		7	11.6	11.7	0.1	0.53	0.53	0.00	0.60	0.60	0.00
8848	23.5	4	0	0	0.0	0.10	0.09	0.01	0.76	0.78	0.02
		5	1.5	1.5	0.0	0.21	0.22	0.01	0.72	0.75	0.03
		6	2.1	2.2	0.1	0.28	0.23	0.05	0.74	0.74	0.00
		7	10.1	10.1	0.0	0.46	0.46	—	0.74	0.74	0.00
8863	24.3	4	0	0	0.0	0.44	0.44	0.00	0.68	0.68	0.00
		5	1.7	1.7	0.0	0.37	0.38	0.01	0.67	0.67	0.00
		6	1.5	1.5	0.0	0.44	0.46	0.02	0.68	0.66	0.02
		7	10.3	10.3	0.0	0.56	0.60	0.04	0.66	0.62	0.04
8788	25.6	4	0	0	0.0	0.68	0.69	0.01	0.40	0.40	0.00
		5	1.7	1.7	0.0	0.53	0.53	0.00	0.82	0.84	0.02
		6	4.5	4.5	0.0	0.55	0.54	0.01	0.80	0.81	0.01
		7	11.3	11.2	0.1	0.53	0.53	0.00	0.70	0.70	0.00
8825	26.0	4	0	0	0.0	0.54	0.54	0.00	0.66	0.66	0.00
		5	1.6	1.6	0.0	0.50	0.50	0.00	0.67	0.67	0.00
		6	2.4	2.4	0.0	0.54	0.53	0.01	0.68	0.68	0.00
		7	9.7	10.3	0.6	0.51	0.49	0.02	0.69	0.69	0.00
8897	26.5	4	—	—	—	—	—	—	—	—	—
		5	1.6	1.6	0.0	0.54	0.56	0.02	0.72	0.73	0.01
		6	2.9	3.0	0.1	0.39	0.39	0.00	0.77	0.75	0.02
		7	9.6	7.8	0.8	0.47	0.46	0.01	0.65	0.68	0.03
8680	28.5	4	—	—	—	0.54	0.53	0.01	0.55	0.55	0.00
		5	—	—	—	—	—	—	—	—	—
		6	2.4	2.4	0.0	0.62	0.63	0.01	0.53	0.52	0.01
		7	11.3	11.2	0.1	0.55	0.55	0.00	0.50	0.50	0.00

GIA

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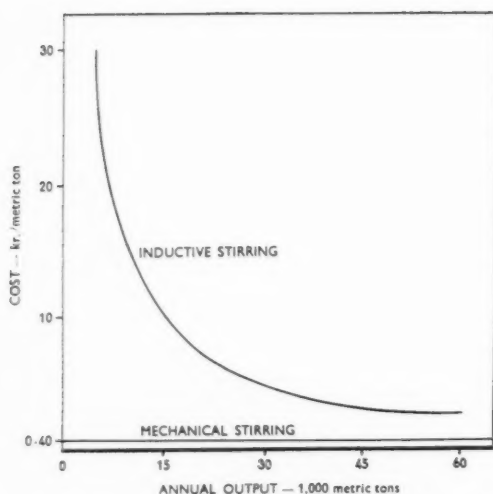


Fig. 4—Costs of mechanical and inductive stirring in relation to the annual production of a furnace of 30 metric tons capacity.

**Maintenance and Repairs of Power Equipment.**—This is estimated at 0.10 Kr./ton of steel, the annual cost being

$$45,000 \times 0.10 \text{ Kr.} \\ = 4,500 \text{ Kr.}$$

**Total Cost.**—The total annual cost is thus 18,000 Kr. or 0.40 Kr./metric ton.

**Inductive Stirring.**—The figures for inductive stirring are based on particulars given by Hammarlund<sup>2,3</sup> using a factor of 1.4 in converting Swedish Kroner to Norwegian Kroner.

**Capital Costs.**—Depreciation of the stirrer, installation, etc., is given as

$$140,000 \text{ Kr.}$$

but neither the period of depreciation nor the basis for calculation is given.

**Power.**—It is assumed that the stirrer is rated at 180 kW. and is in use for 2 hr. per heat. The cost of electricity is taken as 0.02 Kr. per kWh., whereas Hammarlund used a figure of 0.05 Kr. (Swedish) per kWh. The total power cost is thus

$$180 \times 2 \times 0.02 \times 1,500 \text{ Kr.} \\ = 10,800 \text{ Kr.}$$

**Other Costs.**—Hammarlund puts the cost of cooling water, expendable items, maintenance, etc., at 0.21 Kr./metric ton. This amounts to an annual expenditure of

$$0.21 \times 45,000 \text{ Kr.} \\ = 9,450 \text{ Kr.}$$

**Total Costs.**—Rounding off the last figure to 9,500 Kr., the total annual cost amounts to 160,300 Kr. or 3.56 Kr./metric ton.

From the foregoing, it will be seen that the cost of stirring is 3.16 Kr./metric ton more in the case of inductive stirring than for mechanical stirring under the conditions outlined above.

The cost of stirring, expressed in Kr./metric ton, is shown graphically as a function of the annual output of

a 30 ton furnace in Fig. 4. As will be seen from this graph, the cost/ton of mechanical stirring is independent of the amount produced, whereas the cost of inductive stirring increases rapidly with decreasing output.

This point is of special interest in the case of installations with a fairly low annual output—e.g., steel foundries. In a foundry with an annual output of about 5,000 metric tons, the cost will, according to Fig. 4, be approximately 30 Kr./metric ton, with inductive stirring, while the corresponding figure for mechanical stirring is approximately 0.40 Kr.

Beside the factors mentioned above, the laws of depreciation must be taken into account—laws which today vary greatly from country to country. Favourable laws of depreciation can undoubtedly be the decisive factor in a purely economic assessment.

Finally, reference may be made to the fact that one of the essential requirements for the installation of an inductive stirrer is a non-magnetic base plate, and a fairly extensive rebuilding may be required in the case of older furnaces. Furthermore, older furnaces often have a smaller capacity, so that the costs of stirring per ton of steel become relatively high.

### Conclusion

Power operated mechanical stirring and inductive stirring are the methods of greatest interest today in the production of quality steel in electric arc furnaces. Methods of reladling have gained some ground in connection with the production of high alloy steels, while methods based on blowing through gases and metallic vapours, or on rotating furnaces, are of lesser importance.

Normally, in the production of steel in electric arc furnaces, stirring is of no importance until the refining stage is reached. Both the mechanical and the inductive methods can then be used to give satisfactory mixing of the bath, resulting in uniform composition and temperature.

Both methods increase the speed of the reaction between steel and slag, and thus improve deoxidation and desulphurisation. As the inductive method gives continuous stirring, it will undoubtedly effect more speedy refining under some conditions than can be obtained by mechanical stirring under those same conditions. However, no data which can throw more light on this point are available.

It may therefore be assumed that inductive stirring is preferable to mechanical stirring, mainly in those cases where continuous stirring during the refining stage may be utilised to advantage.

### Acknowledgment

The author is greatly indebted to Director A. Ihlen, for his kind permission to publish the results of experience gained at A/S Strømmens Værksted, Oslo—data which form the basis of this article.

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## Steelmaking Centenary Commemorated

### The First Production of Bessemer Ingot Steel in Sweden

A CEREMONY was held on Friday, July 18th, on the original site of the old blast furnace at Edsken in Sweden, to commemorate the centenary of the first mass production of ingot steel in the world. This furnace was erected by G. F. Göransson in 1857 to experiment with the production of steel by the Bessemer process. The process was highly promising and had given good results in a number of single practical experiments, but there were difficulties in the way of regular steel ingot production. Göransson was the first to overcome these difficulties, making his first steel by the process in July 1858. From these early experiments has come one of the most famous names in steel manufacture—Sandviken.

The site was visited by leading personalities of the iron and steel industries in Sweden, and Great Britain was



The gold medal presented to Sandviken Jernverks by the Swedish Iron Masters Association (Jernkontoret) to commemorate the centenary of the first mass production of ingot steel according to the Bessemer process.



The remains of the original blast furnace at Edsken, with a replica of the converter in which ingot steel was first produced by the Bessemer process.

represented by Mr. K. Headlam-Morley, secretary of the Iron and Steel Institute. About thirty remaining descendants of Göransson were also present. At a banquet in the evening, a gold medal was presented to the Sandviken company by the Swedish Iron Masters' Association. The Association is one of the oldest in the world, and its history goes back more than two hundred years. Mr. Headlam-Morley brought with him a personal message of congratulations from Mr. D. Bessemer, the great-grandson of Henry Bessemer. He also formally presented to Mr. W. Hagland, managing director of Sandvikens Jernverks, for inclusion in the company's museum, a sample of the first Bessemer steel rail rolled in England.

#### Belfast Welding School

A NEW welding school to serve industry in Northern Ireland will be opened on October 1st by British Oxygen Gases, Ltd. It will be sited at the company's headquarters at Castlereagh, Belfast. The school will provide tuition in both oxy-acetylene welding and cutting and electric arc welding, and a full-time instructor will be in attendance. Enquiries will be welcomed from any firms wishing to send their operators to the school to receive tuition.

# Metallurgy in Nuclear Engineering

## Survey of the Literature in 1957\*

By J. Burkett, F.L.A.

Information Officer, Hawker Siddeley Nuclear Power Co., Ltd.

*Although nuclear engineering is a comparatively new development, and in spite of the fact that much of the work carried out in this field cannot be published for security reasons, there is a growing volume of literature on the subject, as will be seen from the following pages, in which reference is made to those papers published last year which dealt with metallurgical aspects.*

(Continued from page 36 of the July issue)

### Metallurgy of Reactor Fuels

#### Thorium.

Bell<sup>97</sup> considers the application of thorium to nuclear engineering and outlines the relevant physical, mechanical and chemical properties, particularly its compatibility with other reactor materials. Howe<sup>98</sup> reviews the nuclear reactions of thorium and the production of U233 in such reactors as the CETR, SGR and LMFR. His survey includes the properties of thorium and its alloys, the preparation of slurries, the refining of spent elements and the cost of fuel. Frye *et al.*<sup>99</sup> report at some length on the metallurgy of thorium and its alloys and Danielson *et al.*<sup>100</sup> have investigated the physical properties of unalloyed thorium, the mechanical properties of production thorium, and the effect of impurities on the physical properties. A comprehensive survey on the production, fabrication, physical properties and metallurgy of thorium and thorium alloys has been presented by Wilhelm *et al.*<sup>101</sup> and another critical examination of these properties is given by March and Keeler.<sup>102</sup> A new electrolytic process has been developed for the preparation of pure thorium metal, and Rayner *et al.*<sup>103</sup> describe the two practical methods which resulted: (1) the electrolysis of  $KThF_6$  in sodium chloride; and (2) a method based on an all-chloride electrolytic system. Olsen<sup>104</sup> reports preliminary corrosion tests made on thorium and thorium alloys containing 2–6% Cr, niobium, titanium, zirconium and Ti-Zr alloy in distilled water at 95° C. After thorium and uranium oxide slurries had been irradiated, examination by Krohn and McBride<sup>105</sup> indicated no gross changes in the particulate properties. Mickelson and Peterson<sup>106</sup> discuss the limits of solubility of carbon in thorium, and as part of a programme on the study of the alloying behaviour of thorium in combination with other reactor materials, Gibson *et al.*<sup>107</sup> report on the Th-Zr and Th-Hf alloy systems. Phase diagrams were constructed on the basis of electrical resistance, thermal, microscopic and X-ray evidence.

#### Uranium.

Gerasimovsky<sup>108</sup> details the distribution of the minerals of uranium in the earth's crust, together with physical and chemical characteristics. Over 180 million dollars have been invested in uranium plants in South Africa to recover the uranium in effluent slime from gold reduction plants, and Hull and Pinkney<sup>109</sup> describe the method at the Daggafontein Mines, Ltd. plant, whereby

uranium is absorbed from a pure solution of uranyl sulphate containing an excess of free sulphuric acid when passed through a strong base ion exchange resin. Spence and Convey<sup>110</sup> review Canada's activities in the technology of ore processing.

Nichols<sup>111</sup> gives selected values for the mechanical, physical, chemical and metallurgical properties of uranium, together with the effects of irradiation, thermal cycling, alloy additions, etc. Greene *et al.*<sup>112</sup> have arrived at new values for the U235 content of natural uranium, using improved techniques and new materials. The new value given is  $0.71057 \pm 0.00059$  wt.%, compared with the old value  $0.7115 \pm 0.0014$  wt.%. The available information on uranium is being edited at Argonne to provide research workers with a critical evaluation of present status. The first of the series, by Smith,<sup>113</sup> is concerned with thermal conductivity, and another<sup>114</sup> deals with electrical conductivity. In a report on the mechanical properties of rolled uranium rods, Mayfield *et al.*<sup>115</sup> observed that mechanical strength varies with the temperature of rolling. Blumenthal<sup>116</sup> describes research that was initiated for removing contaminants, particularly carbon, from uranium. Various crucible materials were investigated and the effect of addition agents such as nitrogen, tantalum, titanium and zirconium were studied. In a comparison by Beverley *et al.*<sup>117</sup> between atmospheric and pressure leaching of uranium ores, it was found that high-temperature, high-pressure leaching in alkaline solutions reduces leach time by 90–95%. Leach times may be halved by using existing Pachuca tank equipment at moderate temperatures and pressures.

In a study by Zegler *et al.*<sup>118</sup> of the effects of fabrication and heat treatment variables upon the thermal cycling behaviour of uranium, the growth of rolled uranium rod is shown to depend upon the rolling temperature, amount of rolling reduction and the conditions of the material prior to rolling. Cycling variables, particularly heating and cooling rate, have a definite effect on the growth of *beta*-treated uranium. Burke and Turkalo<sup>119</sup>

\* This survey does not include U.K.A.E.A. reports, which are listed monthly in "Lists of Publications Available to the Public." The reports to be found in the references at the end of the survey are those of the U.S. Atomic Energy Commission. These reports are sent to the following depository libraries, from whom requests for loan should be made:—

The Central Public Libraries of Birmingham, Bristol, Kingston-upon-Hull, Leeds, Liverpool, London (Acton), Manchester, Newcastle-upon-Tyne, Nottingham and Sheffield.

In some instances reports are in the form of microcards, and special viewing apparatus is required. The above libraries either possess viewers or will advise about them.

investigated distortions in uranium subjected to repeated cycles of heating and cooling. Under extreme conditions the length may double or treble. Lloyd and Mayfield<sup>120</sup> are particularly concerned with the changes of uranium during thermal cycling pertaining to the magnitudes of grain boundary interactions as related to their relative orientations and to the mechanisms. Coarse-grained specimens deform by slip, twinning and localized interactions at the boundaries, whilst fine-grained specimens deform by grain interaction and grain boundary migration, together with some intragranular slip and boundary sliding. Chiswick<sup>121</sup> also shows that the growth of *alpha*-rolled uranium rods depends on both preferred orientation and grain size. In a study of the effects of cycling variables on the rate of growth of 300° C. rolled uranium, Mayfield<sup>122</sup> shows that, in general, the greater the temperature range the greater is the resultant growth. Smith *et al.*<sup>123</sup> report on the results of a study of the mechanical constraint of cylindrical specimens of uranium under thermal cycling. The different materials used for the containment jackets included unalloyed zirconium, type 347 stainless steel, tantalum and niobium. Rose<sup>124</sup> describes an apparatus designed for measuring compressive creep of *alpha*-uranium under neutron irradiation.

Shober *et al.*<sup>125</sup> examine the characteristics of uranium alloys that were developed for dimension stability. These include *alpha*-rolled *alpha*-annealed, *alpha*-rolled *beta*-treated, and *alpha*-rolled *gamma*-treated alloys thermal cycled from 100–500° C. Kittel and Paine<sup>126</sup> have studied the effect of irradiation on powder compacts of uranium and some uranium-base alloys, including uranium hydride, a molybdenum alloy, a niobium alloy and a silicon alloy. A similar study is reported by Kittel *et al.*<sup>127</sup> on some corrosion-resistant fuel alloys satisfactory for operation in a heterogeneous power reactor, where dimensional stability is a necessity, and a pressurized water reactor, where, if the fuel cladding were to fail, there would be the danger of rapid uranium corrosion. A U-Nb alloy was found to be unsuitable. A U-Zr-Nb alloy nominally stabilized under irradiation, but corrosion resistance was destroyed by 0.046 and 0.074 at.% burn-up. A U-Si combination was found to be relatively stable and showed no increase in corrosion rate at 290° C., at 0.090 at.% burn up. Macherey and Dunworth<sup>128</sup> describe methods developed at Argonne for casting and fabricating binary alloys of uranium with molybdenum, aluminium, silicon, titanium and vanadium. Bustrom *et al.*<sup>129</sup> examine the properties of uranium-base alloys without protective cladding that have been developed as corrosion resistant in high-temperature water. Saller and Rough<sup>130</sup> have determined various physical and mechanical properties, including radiation damage, of high-uranium alloys containing zirconium or chromium. High-carbon zirconium alloys are much inferior to the low-carbon zirconium alloys and high-carbon chromium alloys. High carbon content does not greatly affect the properties of the chromium alloys.

Bean and Macherey<sup>131</sup> examine the feasibility of roll cladding U-Nb alloys with Zircaloy-2 for plate-type fuel elements: a summary is given of various tests carried out. In a study by Draley *et al.*<sup>132</sup> of the high temperature aqueous corrosion of uranium alloys containing minor amounts of niobium and zirconium, the niobium alloys show good corrosion resistance in degassed distilled water to about 315° C.: alloys containing 3% Nb and small amounts of tin seem promising.

Teitel<sup>133</sup> presents the phase diagram for the U-Bi system. Three intermetallic compounds have been determined, UBi<sub>2</sub>, U<sub>3</sub>Bi<sub>4</sub>, and UBi, whilst the solubility of uranium in liquid bismuth has been calculated up to 900° C. Abmann and Baldwin<sup>134</sup> investigated the phase equilibria of the U-Bi alloys by thermal and chemical analyses. They also identified the compounds UBi and UBi<sub>2</sub>, with UBi melting above 1,500° C., and UBi<sub>2</sub> decomposing peritectically at 980° C. Kaufmann<sup>135</sup> describes early experimental work in determining the U-Si phase diagram, and discusses some of the properties of intermediate phases, whilst Isserow<sup>136</sup> gives details of the U-Si and U-SiO<sub>2</sub> *epsilon* phase, with particular reference to their properties for resistance to water corrosion. The maximum rates of U/AlSi diffusion at temperatures of 200, 250 and 300° C. have been determined by Green.<sup>137</sup>

Douglass and Marsh<sup>138</sup> observed the effect of heat treatment on the hardness and microstructure of U-Ti alloys. Quench-temper or isothermal treatments were particularly effective. Murphy<sup>139</sup> explored the possibilities of improving the mechanical properties of uranium and its resistance to corrosion by adding small amounts of titanium. Increasing amounts of titanium increase strength, hardness and resistance to corrosion, but ductility and impact strength are impaired.

In a survey of project literature by McWhirter and Draley<sup>140</sup> on the aqueous corrosion of uranium alloys, the effect on Nb-U, Mo-U, Si-U, Zr-U and Al-U alloys was included. Mallett and Trzeciak<sup>141</sup> studied the relationships in the U-UH<sub>3</sub>-H system, the stability of hydrogen in massive uranium, sorption of hydrogen by powdered uranium, and equilibrium pressures for the plateaux of the pressure-composition isotherms. Phase diagrams have been constructed. Bauer *et al.*<sup>142</sup> investigated the solid solubility of uranium in thorium. The solubility lies between 1.5 and 2 wt.% U at 1,000° C., and between 0.5 and 1 wt.% U at 800 and 900° C.: it is less than 1 wt.% U below 800° C. The hardness was found to increase with increasing uranium content up to between 3 and 5 wt.% U.

#### Uranium Dioxide.

At a nuclear metallurgy symposium on uranium and uranium dioxide, papers were read on melting, casting, forging, rolling, cold working and welding of uranium; and on the preparation and fabrication of UO<sub>2</sub> into fuel elements.<sup>143</sup> The trend towards high-temperature reactors has fostered an interest in refractories, either alone or in combination with metals, for use in fuel elements operating at temperatures of 1,000° C. and higher. Hausner and Mills<sup>144</sup> point out the special properties such as adequate strength at elevated temperatures, low thermal expansion, good corrosion resistance and stability against radiation damage. Lewis<sup>145</sup> considers the development of a high performance uranium oxide fuel. He compares flat with round rods, discussing neutron losses and heat transfer rates operating near the melting point. Williams *et al.*<sup>146</sup> examine the possibilities of refractory uranium compounds that are corrosion resistant in water systems and have good irradiation behaviour. Zirconium, thorium and silicon are considered as effective bonding metals. Johnson *et al.*<sup>147</sup> review the usefulness of UO<sub>2</sub> for fuel elements, both in bulk and granular forms, and discuss physical properties, oxidation behaviour and reactions. Vaughan *et al.*<sup>148</sup> investigated methods of preparing UO<sub>2</sub> to yield sintered bodies of



high density, whilst Abraham *et al.*<sup>149</sup> studied suspensions of  $\text{UO}_2$  in Na-K alloys for fast breeder reactors. Small additions of uranium stabilize the slurry, enabling it to be circulated successfully at 600° C. There appeared to be no corrosion or erosion of stainless steel tubing. The corrosion of ceramic oxides by molten uranium and its alloys was examined by Feder *et al.*<sup>150</sup>, who studied dense, high-purity alumina, magnesia, zirconia, beryllia and thoria, in the temperature range 1,140–1,330° C.

#### Plutonium.

Bagley<sup>151</sup> reviews the chief characteristics of plutonium and its alloys, including its occurrence and availability, extraction, compatibility with the liquid metals and gases, fabrication and handling.

#### Welding of Materials for Nuclear Reactors

Many of the problems inherent in welding techniques for nuclear power plants are discussed in papers presented at a Symposium held in London in the Autumn.<sup>152</sup> Lucey *et al.* comment on welding developments applicable to the fabrication of heavy pressure vessels, and McLean and Forrest describe the fabrication, erection and welding of the Dounreay sphere, whilst the problems of joining the various metals in DIDO and at Calder Hall are detailed by Shuttleworth and Moore. Hogg considers the welding problems of advanced reactors, especially the possibility of repair of reactors under radioactive conditions. Elsewhere,<sup>153</sup> Hogg details the methods used by the U.K. Atomic Energy Authority to overcome the particular problems confronting the welding engineer.

The development of techniques for welding thick steel plate of 3 in. or more is described with particular reference to the Fortrex 35A electrode, which overcomes the problem of brittle fracture at on-site welding.<sup>154</sup> Laithwaite<sup>155</sup> describes the design, joining techniques, preparatory work and installation of some 45 miles of piping for the burst-cartridge detection gear in the Calder Hall reactors, whilst Ireland<sup>156</sup> covers the welding procedures used at the Windscale Works during construction, and the special methods adopted for plant modifications and maintenance operations. The work involved at Dounreay and at Berkeley in welding stainless steel for the main reactor vessels, pipe work and heat exchanger units has been reviewed.<sup>157</sup> Test procedures were developed for ensuring that no leaks existed between inner and outer pipes or between outer pipes and the atmosphere. A further account of the welding procedures and equipment used for the tubular heat exchangers at Dounreay is given by Griffiths,<sup>158</sup> who discusses radiographic examination and gas testing of all joints in detail. Aluminium is especially suitable for the container of light or heavy water moderated reactors operating at normal temperatures and pressures, and Lancaster<sup>159</sup> discusses the problems of welding dissimilar and variable thicknesses of pure aluminium plate, and of cracking that is apparent in 99.8% purity aluminium filler welds.

Waterfield and Culbertson<sup>160</sup> examine the effect of metallurgical properties on welding techniques for certain austenitic heat- and corrosion-resistant alloys under conditions which make stainless steels and other less noble alloys of little use: they discuss six alloys, four nickel-base, one cobalt-base and one iron-base. Gross and Stout<sup>161</sup> describe the properties and weldability of high-strength pressure vessel steels in heavy sections, and Leonard and Thompson<sup>162</sup> detail the special pro-

cedures developed for welding spherical pressure vessels made of carbon-steel plate clad with type 347 stainless steel, where access for welding is only from the carbon steel surface. Pierce<sup>163</sup> reports on the design and fabrication of equipment for sealing stainless steel cylinders containing radioactive materials, by remotely-operated shielded-arc welding.

In the arc welding of vacuum- and inert-atmosphere-melted Zircaloy-2, there is a variance in the anode heat output. Ludwig<sup>164</sup> considers that this is due to diffusion and evaporation of chlorine and hydrogen from the arc-melted anode surface. Gerken<sup>165</sup> describes a diffusion bonding process where satisfactory bonding was obtained between  $\frac{1}{8}$  in. o.d.  $\times$   $\frac{1}{8}$  in. wall stainless steel and Zircaloy tubing. The joints did not fail after thermal cycling 200 times between 100 and 600° F. (40 and 315° C.), or after pressure cycling 100 times between 100 and 3,500 lb./sq. in. Failure of well-bonded joints occurred only after hydraulic bursting pressures of 13,200–17,200 lb./sq. in.

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# New Magnesium Alloys

By R. J. M. Payne, B.Sc., F.I.M., and N. Bailey, B.Met.

J. Stone & Co. (Charlton), Ltd.

*A series of magnesium alloys has recently been developed whose potential usefulness has been demonstrated in both cast and wrought conditions. Known as the M.S.R. alloys, they contain silver, rare earth metals and zirconium, and have higher proof stress figures than existing magnesium alloys.*

**M**AGNESIUM alloys have now been available to the designer for some decades and are firmly established for many engineering applications. A variety of alloys is available in the usual cast and wrought forms, offering by selection good mechanical properties at elevated temperatures, good short term and long term properties at elevated temperatures, good working qualities, and so on. With appropriate protection—and the epoxy resins are a good standby in difficult cases—corrosion is no longer the bogey that it once was, and on technical grounds magnesium alloys, with their density of about 1·8, offer much to the designer to whom weight is important: at a more practical level, and taking advantage of their unsurpassed machinability, they offer the further possibility of making significant savings in workshop costs.

There is, however, one characteristic—the proof stress—the values for which do not, in magnesium, rise to the level which might be desired. It is natural that comparisons should be made with aluminium-base alloys, and when considering castings for structural purposes it is appropriate to make comparisons only with those aluminium-base alloys showing some few per cent elongation in a tensile test: the fully hardened aluminium alloys which show the highest proof stresses are brittle, and for that reason find practically no application for structural purposes. On comparing the properties of such aluminium alloys with those of the magnesium alloys (see Table I) it will be seen that the proof stress of TZ 6, while exceeding that of the aluminium alloy to D.T.D. 298, falls short of that of L. 53 and D.T.D. 304; comparisons between the specified proof stresses for wrought magnesium-base and aluminium-base alloys show greater divergencies. In view of this situation, and because proof stress values constitute one of the bases of design, it is understandable that some effort should have been made in this country and elsewhere to improve the proof stress of magnesium alloys.

## Two-Stage Heat Treatment

A natural line of thought would be to take advantage of two-stage (solution + precipitation) heat-treatment processes such as are widely used with aluminium-base and other alloys. Up to the present time, however, this has not proved rewarding. Some limited use has been made of fully heat-treated magnesium-aluminium-zinc alloys of the AZ 91 type, and (in the United States and Canada) of the magnesium-thorium-zirconium alloy HK 31, used where particular high temperature properties were required. Again in America there is some limited use of the magnesium-zinc-zirconium alloy ZK 61. The tensile properties developed in the AZ 91 and HK 31 type alloys are not impressive, and

TABLE I.—MECHANICAL PROPERTIES OF SOME MAGNESIUM-BASE AND ALUMINIUM-BASE CASTING ALLOYS

Alloy Designation and Specification	Nominal Composition	Mechanical Properties		
		0·1% Proof Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Elongation (%)
RZ 5 (D.T.D. 748)	Mg-4·5% Zn-1·25% R.E.-0·7% Zr	8	13	3
Z5Z (D.T.D. 721A)	Mg-4·5% Zn-0·7% Zr	8·5	15	5
TZ 6 (Draft spec'n.)	Mg-5·5% Zn-1·8% Th-0·7% Zr	9	16·5	5
D.T.D. 298A	Al-4·5% Cu	(8)	14	7
D.T.D. 304A	Al-4·5% Cu	(12)	18	4
L. 53	Al-10% Mg	(10)	18	8

The figures given in the table are in general specified minimum values: the brackets indicate that proof stress determinations are not mandatory in the case of aluminium alloys, and the figures quoted are given in the relevant specifications for information only.

the ZK 61 alloy, although showing a very useful combination of proof stress, ultimate stress and elongation has a major disqualification in its marked hot shortness, which makes the founding of large and complex shapes difficult, and the rectification of minor casting faults by welding impossible. With other magnesium alloy systems the results of subjecting alloys to two-stage heat-treatment have been disappointing, and in many instances the properties of fully heat-treated alloys have been actually inferior to those of material handled in other and simpler ways: it is for this reason that almost the whole of the present magnesium casting production is based on compositions developing their properties by simple ageing treatment, and that most wrought alloys derive their properties from some degree of cold working.

In this situation a new series of magnesium-base alloys in which the properties are developed by two-stage age-hardening treatment will be of interest. These alloys, which were established in the course of research carried out at J. Stone & Co. (Charlton), Ltd., are essentially magnesium-silver-rare earth metals-zirconium alloys, the silver and R.E. metals comprising the main hardening constituents. The potential usefulness of these alloys has been demonstrated in both cast and wrought conditions, but the present article is mainly concerned with cast products. The M.S.R. alloys now being offered for casting purposes contain 1·3-5% silver, 1·3-5% R.E. metals, and 0·4-1% zirconium. Proof stresses exceeding 13½ tons/sq. in. have been obtained with this class of alloy in the cast condition (D.T.D. test-bar), but at this level elongation values are low.

Higher elongation values can be secured, but this entails a sacrifice of proof stress. While the views of industry are being sought as to the preferred balance between proof stress and elongation, castings are currently



Bar Identification	Test Piece Dimensions		0.1% Proof Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Elongation (%)
	Diameter (in.)	Gauge Length (in.)			
A	0.564	2	11.45	16.4	3.5
B	0.564	2	11.55	16.6	4
C	0.427	1.5	11.2	15.7*	3*
D	0.378	1.25	11.05	16.9	5.5
E	0.564	2	—	16.6	4
F	0.564	2	11.45	17.2	7
G	0.564	2	11.65	17.3	6.5
H	0.564	2	11.15	17.3	7
		Mean Values	11.4	16.9	5.4
Separately Cast D.T.D. Test-bars from the Same Melt Heat-Treated with the Casting	0.564	2	12.0	16.8	3
	0.564	2	12.0	17.5	7
	0.564	2	11.85	17.2	5
		Mean Values	11.95	17.2	5

\* Inclusion : result not used in arriving at mean values.

Fig. 1.—Results of tensile tests on specimens cut from the casting shown above, having a maximum dimension of 24 in., a maximum section thickness of 1½ in., a depth of 3 in. at the inner flange, and a fettled weight of 12½ lb.

being offered in material conforming to two specifications, which are as follows :—

Specification	0.1% Proof Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Elongation (%)
A	10 min.	15 min.	4 min.
B	11 min.	15 min.	2 min.

These specifications are put forward tentatively, and in the absence of experience in heat-treating castings in real production quantities. Castings treated so far in production furnaces have given tensile figures in excess of those quoted, and it is possible that the specified minimum values may be improved upon with further experience.

#### Improved Proof Stress

It will be seen that even with the A specification, the proof stress of the new alloy is higher than for existing magnesium alloys and directly comparable with that of the aluminium alloy L.53. It will also be noted that the ultimate stress of the material is sufficiently high in relation to the proof stress to permit full advantage being taken of the improved proof stress values in design. It will be appreciated that with the further advantage of a density 40% lower than aluminium alloys the M.S.R. alloys are particularly attractive.

The M.S.R. alloys have good casting qualities and are free from hot-tearing or hot-cracking tendencies. They are fully weldable. Pressure tightness is good, as with other magnesium-R.E.-zirconium alloys, and the alloys

show a resistance to creep comparable with that of ZRE 1 or MCZ at 200° C. The corrosion resistance is not significantly different from, and certainly not inferior to, that of some other magnesium alloys in regular use. The alloys do not appear to be liable to failure by stress-corrosion.

It would be expected that the use of two-stage heat-treatment processes would promote a high degree of uniformity of properties in thin and thick sections of castings, and a good correspondence between these and the properties of separately cast test-bars. The accompanying results of "cut up" tests on an actual casting (Fig. 1) show that this is in fact achieved, and tests on even heavier castings show an improvement in proof stress of some 40% over that possible with the strongest existing magnesium alloys. While the improvement in tensile values in test-bars are real and significant, the improvement in properties in actual castings is even more impressive, and provides a full and perhaps more realistic justification for the introduction of the new alloy.

The alloys referred to above contain zirconium and fall within the broad coverage of certain alloy and process patents owned by Magnesium Elektron, Ltd., under which J. Stone & Co. (Charlton), Ltd., are licensed. These particular compositions, however, form the subject of a new patent application. For the present, development work will be continued by J. Stone & Co. (Charlton), Ltd., although eventually the alloys will probably be manufactured by other foundries as well.

### Investment Casting Award

AN innovation at this year's annual congress of the European Investment Casters Association was the presentation of castings submitted by various participants with a view to bringing into focus for the benefit of all concerned the present-day scope and application of the lost-wax casting process, highlighting specific problems overcome, developments of technique, and castings of which the manufacturers have reason to be particularly proud.

One of the two diplomas was awarded to Firth-Vickers, for "the casting showing the greatest promise for widening the scope of the investment casting technique." The casting referred to was one of five in non-magnetic alloy steel which, after minor finish machining, drilling and tapping of holes, are assembled to form the chassis of an artificial horizon gyroscope.

### House Magazine Award

FOLLOWING the award of a Certificate of Merit in this year's National House Journal Competition organised by The British Association of Industrial Editors, *Noral News*, the works magazine of Northern Aluminium Co. Ltd., has now received a similar award in the 1957 Awards Program sponsored by the International Council of Industrial Editors, which has its headquarters in the U.S.A. Two years ago *Noral News* won an Award of Excellence in this annual competition and has, in addition, collected three awards in the annual British contest. In the recent international competition, there were over 900 entries received from various parts of the world. The editor of *Noral News* is Mr. G. G. Walker of the Company's Publicity Division, Banbury, and the printers are Cheney & Sons, Ltd., Banbury.

# The Pack Carburising and Annealing of 4 $\frac{1}{4}$ % Ni-Cr-Mo Case Hardening Steel

By C. Dawes, A.I.M.

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Various compounds have been used to carburise a 4 $\frac{1}{4}$ % nickel-chromium-molybdenum steel, and the influence of these on the "as quenched" hardness, microstructure, carbon content and annealing characteristic of the carburised case is described. Recommendations are made for a carburising compound which will prevent the formation of heavy carbide networks and for a standard annealing treatment. This second section of the article is concerned with the annealing aspect.

(Concluded from page 9 of the July issue)

## ANNEALING FOR MACHINING Metallurgical Considerations

### Retained Austenite

IN considering the annealing of high alloy carburising steels, probably the most important factor is the percentage of retained austenite in the carburised case. The amount of austenite retained at atmospheric temperature is determined by the temperatures at which martensite transformation starts and finishes, i.e.,  $M_s$  and  $M_f$ . These temperatures are determined by the chemical composition of the case, the temperature of carburising or heating, and the rate of cooling.

**Chemical Composition.**—A number of formulae have been proposed for calculating  $M_s$  temperatures from chemical composition. One of the more accurate of these is that due to Steven and Haynes,<sup>1</sup> which may be stated as:

$M_s (^{\circ}\text{C.}) = 561 - (474 \text{ C} + 33 \text{ Mn} + 17 \text{ Ni} + 17 \text{ Cr} + 21 \text{ Mo})$ .  
The temperature at which martensite ceases, i.e.,  $M_f$ , is more difficult to determine. The limited data available suggest that the temperature difference between  $M_s$  and  $M_f$  is approximately 100° C., but is increased markedly by increase in carbon content.

For a steel of composition C 0.15%, Mn 0.50%, Cr 1.25%, Ni 4.25%, Mo 0.20%; which has been carburised:—

- (1) The calculated  $M_s$  for the core is 376° C., with an  $M_f$  of approximately 210° C.
- (2) The calculated  $M_s$  with a carburised case of 0.70% C is 115° C., with an  $M_f$  of approximately 20° C.
- (3) The calculated  $M_s$  with a carburised case of 1.00% C is -27° C., with an  $M_f$  of approximately -150° C.

This illustrates the relative effect of carbon on the amount of austenite retained in a carburised case. As the  $M_s$ - $M_f$  range is depressed below atmospheric temperature by increasing carbon, so more austenite is retained.

Retention of austenite at atmospheric temperature in a hypereutectoid case must, therefore, be expected. However, it has already been shown in the first part of this article that a eutectoid case less likely to form retained austenite can be obtained by controlling the energiser strength of the compound.

**Temperature of Heating.**—The formula for calculating an  $M_s$  temperature from chemical composition assumes complete and uniform solution of all the carbon in the austenite. It will readily be seen that the carbide in a eutectoid case is almost completely dissolved at the eutectoid temperature and, therefore, a higher temperature will not effect the composition of the austenite as no further carbide remains to be dissolved.

On the other hand, a hypereutectoid case which has been heated at the eutectoid temperature will have the same  $M_s$  as a eutectoid case, since the excess carbides are out of solution. However, if heated at higher temperatures, the austenite will become increasingly richer in carbon and alloying elements until all the carbides are dissolved. These changes in composition will be accompanied by a depression of the  $M_s$  and  $M_f$  temperatures, thus increasing the quantity of austenite retained at atmospheric temperature.

**Cooling Rate.**—The rate at which a eutectoid case is cooled from a high austenitising temperature, i.e., above the eutectoid temperature, will not effect the composition of the austenite, since no pro-eutectoid carbon is available to precipitate out.

When a hypereutectoid case is quenched from a high austenitising temperature, i.e., above the  $A_{cm}$  temperature, or even cooled fairly quickly as it would be in a small carburising box, then the pro-eutectoid carbon will be held in solution down to the atmospheric temperature, and both  $M_s$  and  $M_f$  temperatures will be depressed. However, if a hypereutectoid case is slowly cooled, as it would be in a large carburising box, the pro-eutectoid carbide will precipitate out at the austenite grain boundaries, thus reducing the carbon content of the austenite. This in turn raises the  $M_s$  and  $M_f$  temperatures, with a corresponding reduction in the amount of austenite retained at atmospheric temperatures.

### Isothermal Transformation

It is evident from published transformation curves,<sup>1</sup> that the core of En 39B transforms too slowly in the pearlite range for the application of either isothermal or continuous cooling annealing. However, since the carburised case transforms faster, it was felt that it might be possible to soften it by isothermal or continuous cooling, although the core would be unaffected.

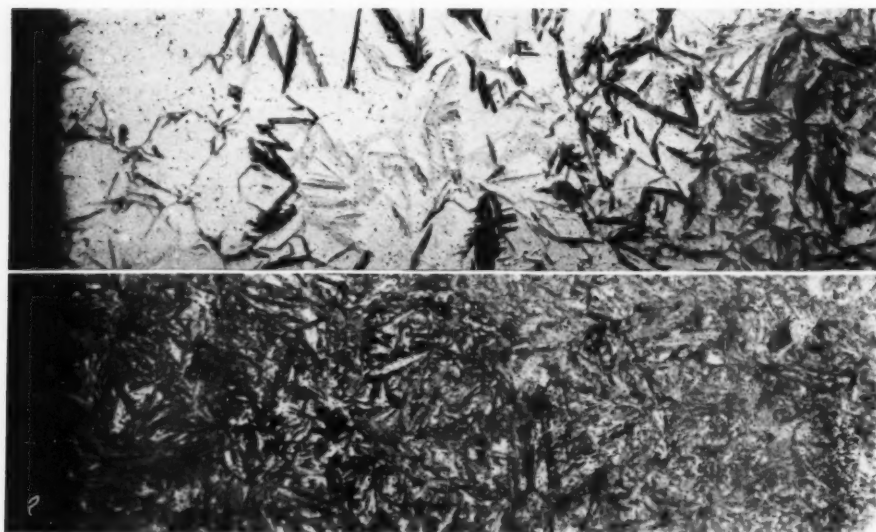


Fig. 6.—Steel to En 39B air cooled from carburising: (a) hypereutectoid case; (b) eutectoid case.  $\times 250$

### Critical Temperatures

The critical points, designated as  $A_1$  and  $A_3$ , are the temperatures at which transformation occurs under strictly equilibrium conditions, which rarely prevail under normal circumstances. Given equilibrium conditions, the lower critical temperature, i.e.  $A_1$ , is the same for both the case and the core for a particular steel, but under non-equilibrium conditions the lower critical temperature of the case is somewhat higher than that of the core. This is probably due to the high carbon case forming alloy carbides, and thereby impoverishing the alloy content of its matrix.

### Experimental Work

A review of the metallurgical considerations, suggested that it would be worthwhile investigating the effect on the core and carburised case of the following factors:—

- (1) Critical temperature.
- (2) Cooling rate from the carburising treatment.
- (3) Sub-critical annealing temperature.
- (4) Multiple tempering.
- (5) A normalising treatment prior to annealing.
- (6) Isothermal annealing.

### Steel Specification

All the samples of steel obtained were in the form of  $1\frac{1}{4}$  in. diameter annealed rod. The bars were machined into 1 in. diameter, 1 in. long test specimens.

### Carburised Specimens

For the tests which are described later, it was thought worthwhile to have two series of carburised specimens: the first, having a eutectoid case, was obtained by pack carburising with 1% sodium carbonate compound; and the second, having a hypereutectoid case, was obtained by pack carburising with 5% sodium carbonate compound.

A mixture of 9 parts of old to 1 part of new compound was used in all the pack carburising treatments, which involved a carburising cycle of 16 hours at  $900^\circ\text{C}$ . to give a case depth of approximately 0.060 in.

### Method of Investigation

**Critical Temperatures.**—Specimens which had been carburised and then annealed to give case hardness values of 32 Rc.\* and core hardness values of 21 Rc., were heated to temperatures from  $650^\circ\text{C}$ . to  $750^\circ\text{C}$ . at  $10^\circ\text{C}$ . increments for 6 hours, and then quenched into oil. The temperature at which the hardness value of the quenched specimen markedly increased was taken as a simple practical estimation of the critical temperature.

**Cooling Rate after Pack Carburising.**—Specimens were cooled from carburising as follows:—

- (a) Air cooled in the atmosphere.
- (b) Air cooled in a small carburising box, i.e., 4 in.  $\times$  4 in.  $\times$  4 in.
- (c) Air cooled in a large carburising box, i.e., 24 in.  $\times$  12 in.  $\times$  12 in.
- (d) Furnace cooled in a carburising box (in this instance approximately  $20^\circ\text{C}/\text{hr}$ ).

**Sub-Critical Annealing Temperatures.**—The specimens cooled at the different rates from carburising (a, b, c and d) were packed in boxes with clean cast iron borings and then sub-critically annealed at the following temperatures:—

- (i)  $580^\circ\text{C}$ . for 1 to 6 hours.
- (ii)  $650^\circ\text{C}$ . for 1 to 6 hours.
- (iii)  $700^\circ\text{C}$ . for 1 to 6 hours.

\* 32 on the Rockwell C Scale.

TABLE IV.—CRITICAL TEMPERATURE DETERMINATION.

Heating Temperature ( $^\circ\text{C}$ )	Soaking Time (hr.)	Hardness (Rc.) As-Oil-Quenched	
		Case	Core
650	6	34	21
660	6	34	23
670	6	32	21
680	6	36	30
690	6	33	30
700	6	32	29
710	6	34	33
720	6	36	38
730	6	38	38
740	6	45	42
750	6	40	43



**Multiple Tempering.**—The specimens cooled at the different rates from carburising (a, b, c and d) were packed in boxes with clean cast iron borings and then given the following multiple tempering treatments:—

- (1) 580° C. for 1 hour, air cooled in box, followed by 580° C. for 1 to 6 hours, air cooled in box.
- (2) 650° C. for ½ hour, air cooled in box, followed by 650° C. for ½ to 6 hours, air cooled in box.
- (3) 650° C. for ½ hour, air cooled in box, followed by 650° C. for ½ hour, air cooled in box, followed by 650° C. for ½ to 6 hours, air cooled in box.
- (4) 700° C. for 1 to 6 hours, air cooled in box, followed by 650° C. for ½ to 6 hours, air cooled in box.

**Normalising Treatments.**—Specimens which, after carburising, had been cooled to room temperature by procedures a, b, or c, were reheated in a neutral salt bath to the minimum temperature, i.e., 750° C., to austenitise the eutectoid carbon, soaked for ½ hour at this temperature and then air cooled to room temperature. These were then given the sub-critical multiple tempering and isothermal annealing treatments.

**Isothermal Annealing.**—The specimens cooled at the different rates from carburising (a, b, c or d) were packed in boxes with clean cast iron borings. These specimens were then austenitised at 750° C. and given a ½ hour soak at this temperature, following which the boxes were transferred to a furnace at 580° C. and held for 1 to 6 hours. The boxes were then removed from the furnace and air cooled to atmospheric temperature.

## Results

After each test the specimen was cut through its axis, and microscopic examination and hardness tests made on the carburised case and the core.

### Critical Temperatures (Table IV)

Under normal practical conditions, the lower critical temperatures for the case and the core are shown to be 720° C. and 675° C., respectively.

### Cooling Rate (Table V)

With hypereutectoid specimens, more austenite retention occurs with the faster rates of cooling, approximately 80–90% being obtained in specimens cooled in air,

TABLE V.—COOLING RATES OF HYPEREUTECTOID CASES.

Treatment after Carburising	Hardness		Microstructure of Case (in terms of distance from surface)
	Case	Core	
Air Cooled in Open Atmosphere	46 Rc.	45 Rc.	0-0-030 in. 80-90% austenite.
	337 V.P.N.*	—	0-030-0-060 in. 100% martensite.
Fast Box Cool	50 Rc.	37 Rc.	0-0-030 in. 60% austenite.
	346 V.P.N.	—	0-030-0-060 in. 100% martensite.
Slow Box Cool	56 Rc.	33 Rc.	0-0-005 in. globular carbide—no austenite.
	616 V.P.N.	—	0-005-0-030 in. 10-20% austenite.
Furnace Cool (20° C./hour)	60 Rc.	32 Rc.	0-0-005 in. globular carbide—no austenite.
	757 V.P.N.	—	0-005-0-060 in.: no austenite detected—networks of cementite.

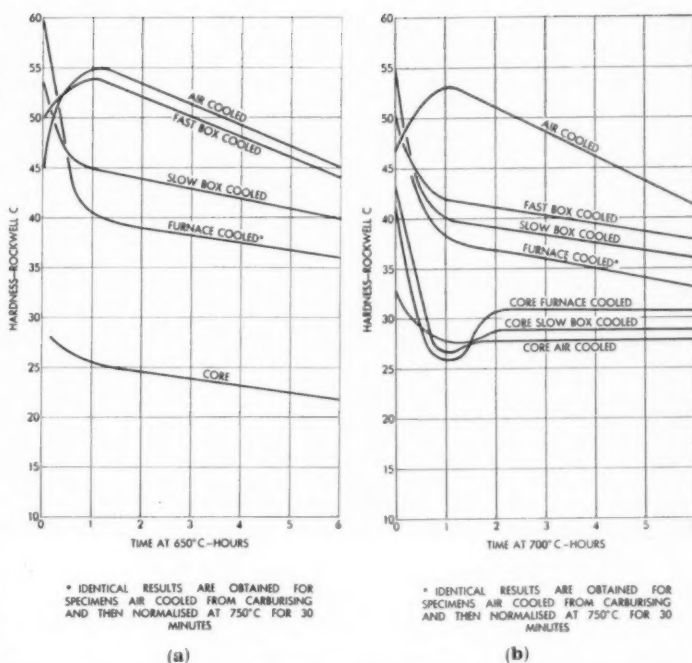


Fig. 7.—Tempering curves for specimens of steel to En 39B with hypereutectoid case, cooled at various rates from carburising: (a) sub-critically annealed at 650° C.; (b) sub-critically annealed at 700° C.

(Fig. 6a), whereas virtually no austenite is obtained in specimens box cooled in a furnace. As would be expected, air cooled samples, which have the largest amount of retained austenite, have the lowest hardness values, i.e., around 46 Rc. (377 V.P.N.)\*, whilst furnace cooled specimens have hardness values around 60 Rc. (757 V.P.N.). With air cooled eutectoid specimens (Fig. 6b), only a small percentage of austenite is retained at room temperature, giving a hardness value around 58–60 Rc.

### Sub-Critical Annealing

**Single Tempering.**—The time/temperature/hardness curves (Fig. 7) for hypereutectoid specimens have the same pattern. With specimens cooled at the faster rates there is some degree of secondary hardening, which is more evident at the lower tempering temperatures. This is due to the retained austenite breaking down to martensite (Figs. 6a and 8a), and after a 1 hour treatment the hardness value increases from 45 Rc. (337 V.P.N.) to 55 Rc. (648 V.P.N.). Fall in hardness values with all specimens is more marked at 700° C. The lowest hardness values obtained throughout the tempering temperature range are on specimens which have been cooled relatively slowly from the carburising treatment. With air cooled eutectoid specimens, similar time/temperature/hardness values (Fig. 9) and microstructure (Fig. 8b) are obtained to the furnace cooled hypereutectoid specimens, no secondary hardening being evident.

Core hardness values are similar for both hypereutectoid and eutectoid specimens, irrespective of the cooling rates, the lowest values, i.e., 21–23 Rc. being obtained with a tempering temperature of 650° C. A significant increase occurs with tempering at 700° C., i.e., 28–31 Rc.

### Multiple Tempering.

—A comparison of these time/

\* V.P.N. figures are for 30 kg. load unless otherwise stated.

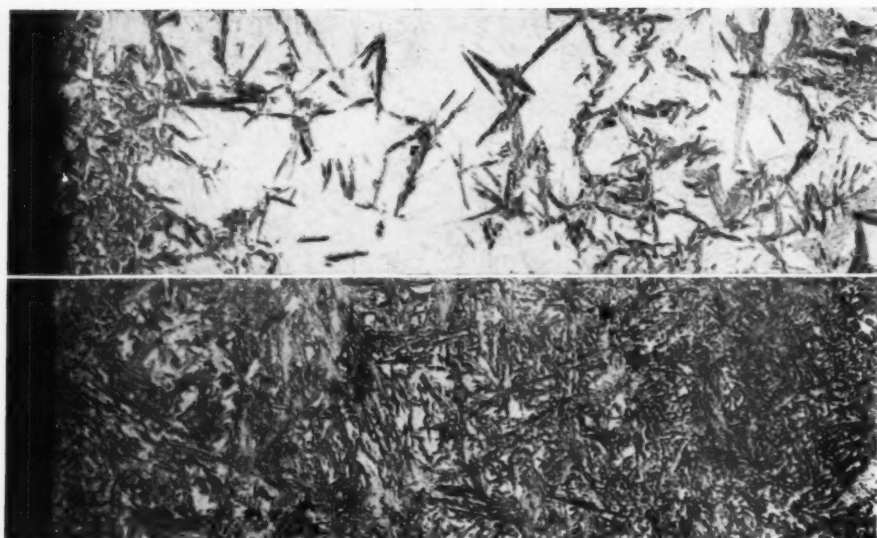


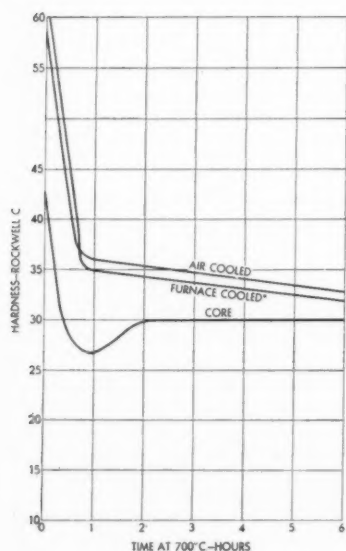
Fig. 8.—Steel to En 39B sub - critically annealed at 700°C. for 6 hours after air cooling from carburising : (a) hypereutectoid case ; (b) eutectoid case.  $\times 250$

temperature/hardness curves (Fig. 10a) with the single tempering curves (Fig. 7) for hypereutectoid specimens, shows that for an equivalent total time, the multiple tempering treatments give lower hardness values on specimens cooled at the faster rates. Fig. 11 shows that the second tempering treatment spheroidises the martensite which forms from the breakdown of retained austenite during the first tempering treatment (Fig. 8a). However, a comparison of the curves in Fig. 7, with those in Fig. 10b, shows that multiple tempering has no advan-

tage over single tempering with relatively slowly cooled specimens.

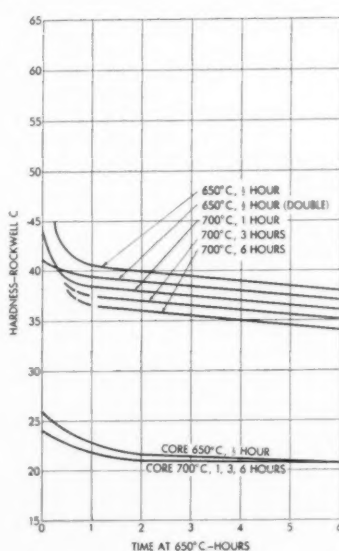
With all the specimens, fall in hardness values is more marked when the first multiple tempering treatment is carried out at 700°C. With air cooled eutectoid specimens, a similar time/temperature/hardness pattern (Fig. 12) is obtained to that with furnace cooled hypereutectoid samples, although somewhat lower hardness values are obtained throughout the temperature range.

Multiple tempering softens the core to lower hardness

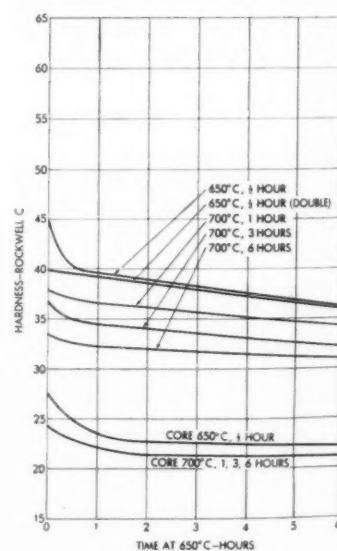


\* IDENTICAL RESULTS ARE OBTAINED FOR SPECIMENS AIR COOLED FROM CARBURISING AND THEN NORMALISED AT 750°C. FOR 30 MINUTES

Fig. 9.—Tempering curves for specimens of steel to En 39B with eutectoid case, air cooled and furnace cooled from carburising and sub-critically annealed at 700°C.



(a)



(b)

Fig. 10.—Tempering curves for specimens of steel to En 39B with hypereutectoid case, multiple tempered : (a) air cooled from carburising ; (b) air cooled from carburising and normalised (equivalent to furnace cooling). The details given on each curve refer to previous treatment.

Fig. 11.—Steel to En 39B with hypereutectoid case. Air cooled from carburising and multiple tempered at 700° C. for half an hour and 650° C. for 3 hours.  
× 250



values than single tempering for an equivalent length of time. The lowest value, i.e., 21 Rc., being obtained when the first multiple tempering treatment is at 700° C. The time held at this temperature, however, appears to have no effect on the final hardness value.

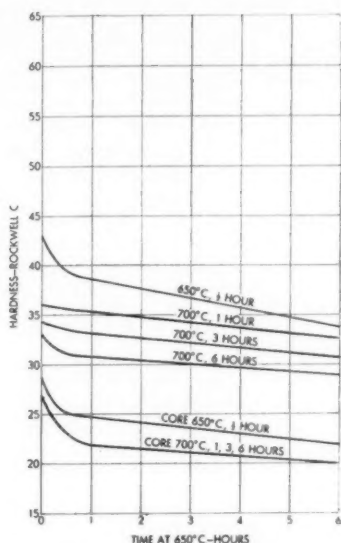
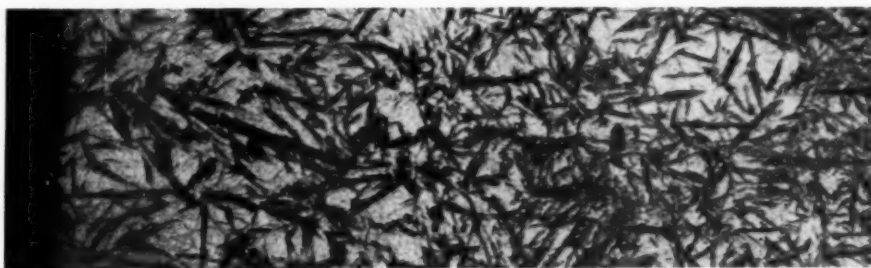


Fig. 12.—Tempering curves for specimens of steel to En 39B with eutectoid case. Air cooled from carburising and multiple tempered. The details given on each curve refer to previous treatments.

#### Normalising Treatment

Hypereutectoid specimens, irrespective of cooling rate from carburising, which have subsequently been normalised at 750° C., have a martensitic structure, which contains virtually no retained austenite, and has a hardness value of 60 Rc. Fig. 13 shows a typical normalised hypereutectoid case, and it will be noted that it is very similar to Fig. 6b, which represents a typical

Fig. 13.—Steel to En 39B with hypereutectoid case. Air cooled from carburising and normalised at 750° C.  
× 250



air cooled eutectoid case. On subsequent sub-critical annealing, the hardness curves for normalised specimens coincide with the curves for furnace cooled specimens (Fig. 7).

Since air cooled eutectoid specimens show very little retained austenite, it is to be expected that normalising has no effect on the time/temperature/hardness curves for sub-critical annealing. Normalising has no influence on the ultimate core hardness of the specimens, irrespective of tempering treatment.

#### Isothermal Annealing

The hardness values of a furnace cooled or normalised hypereutectoid specimen falls to a satisfactory level of 32 Rc. after four hours transformation at 580° C. The hardness value of the faster cooling rate specimens, however, is 40 Rc., even after a transformation time of 6 hours at 580° C. With a normalised eutectoid case, isothermal annealing at 580° C. gives hardness values which coincide with those of furnace cooled or normalised hypereutectoid cases. Core hardness values remain at a very high level, i.e., 35 Rc., irrespective of previous cooling conditions or time at the selected transformation temperature.

### Discussion of Results

#### Carburised Hypereutectoid Case

##### Sub-Critical Annealing

*Single Tempering.*—The effect of tempering on the hardness values of specimens which have been cooled at different rates is shown in Fig. 7. When air cooled specimens are tempered between 580° C. and 700° C., no decomposition of austenite takes place on heating up to temperature, neither is there any decomposition to pearlite during long exposures to temperatures within this range. However, during the tempering treatment, the martensite formed during the cooling from the carburising treatment, decomposes and carbide precipitation occurs. This depletes the carbon and alloy content of the retained austenite and raises its  $M_s$  and  $M_f$  temperatures. Thus, the retained austenite, now weaker in



Fig. 14.—Steel to En 39B with hypereutectoid case. Air cooled from carburising, normalised at 750° C., and subcritically annealed at 700° C. for 6 hours.  $\times 250$

carbon, has become conditioned for transformation on cooling to room temperature.

The cooling product is usually martensite (Fig. 8a), but if the cooling is very slow or interrupted, bainite may form out of the retained austenite and supersede the martensite transformation. Thus, on cooling to room temperature, various mixtures of secondary bainite and martensite replace the retained austenite, with a consequent increase in hardness.

When specimens which have been cooled in a small carburising box are tempered, the secondary hardening effect is still apparent, although not to such a great extent as with air cooled specimens. This is due to the smaller percentage of austenite retained in the box cooled specimens. However, when specimens cooled in large carburising boxes are tempered, no secondary hardening is apparent. In this instance the softening of a predominantly martensitic structure more than counteracts the effect of the breakdown of a small amount of retained austenite. With furnace cooled specimens, no retained austenite is present, so that, on tempering, globularisation, coalescence and segregation of the cementite occurs with a sharp fall in hardness values.

**Multiple Tempering.**—During the first temper, the retained austenite which does not transform isothermally will change to bainite or martensite on cooling. Most of this retained austenite reacts according to the latter procedure, i.e., on cooling. If the  $M_s$  temperature is raised sufficiently by carbide depletion of the austenite, nearly all of the retained austenite will be converted during the cool from the first temper. The second tempering treatment will, therefore, spheroidise the martensite already formed (Fig. 11).

Multiple tempering converts more retained austenite than single tempering, since with single tempering the conditioning of the austenite is aided only by the martensite present in the as-carburised case, whereas with multiple tempering, each cooling procedure produces more martensite to aid the conditioning process. It will be obvious that multiple tempering will have no advantage with specimens containing little or no retained austenite, Fig. 10b confirms this.

#### *Normalising and Tempering.*

If an as-carburised specimen is reheated to 750° C., then only the eutectoid carbon will be taken into solution and the excess carbon will remain as undissolved carbide. On cooling, martensite will begin to form at about 150° C. and this transformation will continue down to room temperature. The final structure will therefore contain virtually no retained austenite, Fig. 13. It was noted that this structure was identical with that obtained by very slow cooling.

If a specimen normalised in this manner is tempered, then the martensite will be spheroidised (Fig. 14), with a consequent fall in hardness, as may be seen from Fig. 7. It will be noted that the tempering reaction at 700° C. is considerably faster than that at 650° C. This is a characteristic behaviour.

#### *Isothermal Annealing*

Isothermal annealing involves austenitising the steel and then allowing it to transform as completely as possible in the pearlitic range. Low austenitising temperatures favour more rapid rates of transformation, and for this reason the minimum temperature necessary, i.e., 750° C., to dissolve the eutectoid carbon was chosen, leaving the excess carbide to serve as nuclei for transformation. Specimens which have been normalised at 750° C. prior to isothermal annealing transform to pearlite in under four hours, giving a hardness value of 32 Rc. Relatively rapidly cooled samples, however, are very sluggish to transformation. This is probably due to the much higher carbon content of the retained austenite in these specimens. The effect of the higher carbon is to move the isothermal transformation curve to the right, that is increase the time before initiation of transformation to pearlite.

#### **Carburised Eutectoid Case**

##### *Sub-Critical Annealing*

**Single Tempering.**—The carbon content of the eutectoid specimens is probably just above the theoretical eutectoid composition, since only a small percentage of austenite is retained after air cooling (Fig. 6b). This austenite, however, will have a much lower carbon content than that retained in hypereutectoid cases. The general effect of the lower carbon content is to move the isothermal transformation curve of the austenite retained to the left, i.e., decrease the time before initiation of transformation. Therefore, with air cooled eutectoid specimens, isothermal decomposition of the retained austenite to pearlite occurs after a relatively short exposure at the higher tempering temperature, and this, together with the simultaneous globularisation of the martensite (Fig. 9), causes a sharp fall in hardness values. The time/temperature/hardness curves for air cooled eutectoid specimens more or less coincide with those obtained for the normalised or furnace cooled hypereutectoid specimens.

**Multiple Tempering.**—It will be obvious that multiple tempering will have no advantage over single tempering when the higher tempering temperatures are used. However, with the lower tempering temperatures, little or no isothermal transformation occurs, probably due to the retained austenite being more sluggish, and the



austenite transforms to martensite on cooling to room temperature. A multiple temper then becomes necessary.

The multiple temper time/temperature/hardness curves for air cooled eutectoid specimens show lower hardness values than the curves for corresponding furnace cooled or normalised hypereutectoid specimens. This may be due to the absence of the globular carbide layer which is usually found on the extreme edge of hypereutectoid cases, especially those carburised with highly energised carburising compounds.

#### *Normalising and Tempering*

As would be expected, due to the small percentage of austenite retained on air cooling, normalising shows no advantage with specimens tempered at the higher temperatures.

#### *Isothermal Annealing*

The isothermal annealing characteristics of normalised hypereutectoid and normalised eutectoid specimens are identical, since the austenitising temperature, i.e., 750° C. will dissolve the same amount of carbon in each case.

#### **Core**

##### *Sub-Critical Annealing*

*Single Tempering.*—On cooling from carburising, because of the low carbon content and consequent absence of carbides, the transformation of austenite to pearlite is very slow, so that the core transforms entirely to martensite and bainite irrespective of the cooling rate. As would be expected, therefore, the time/temperature/hardness curves coincide for specimens cooled at the different rates.

*Multiple Tempering.*—Multiple tempering softens the core more quickly than single tempering for an equivalent total length of time, and this may be due to the presence of small quantities of austenite. It is very likely that the precipitation of pro-eutectoid ferrite and the formation of bainite during cooling are responsible for the retained austenite, since these reactions will increase the carbon content of the parent austenite and thereby depress both the  $M_s$  and  $M_f$  temperatures. Inhomogeneity of the steel when in the austenitic condition may also contribute to the retention of austenite.

#### *Isothermal Annealing*

This type of steel transforms too slowly in the pearlitic range for the application of isothermal or continuous cooling annealing.

#### **Conclusions**

The lower critical temperatures of the case and the core under normal practical conditions are shown to be 720° C. and 675° C., respectively.

Considering the carburised case, it has been shown that the cooling rate from carburising influences the percentage of austenite retained in hypereutectoid specimens, but it has little effect on eutectoid specimens. Single tempering is effective only on specimens which do not contain retained austenite. Retained austenite does not appear in slowly cooled hypereutectoid specimens, but when it does, i.e., with rapidly cooled specimens, it can be removed by a normalising or conditioning treatment prior to the sub-critical anneal. Transformation speed during isothermal treatment is slowed down by the presence of retained austenite left from a previous austenitising treatment.

With the core, the cooling rate from carburising has no influence on the ultimate hardness after sub-critical annealing. Multiple tempering softens the core to lower hardness values than single tempering for an equivalent total length of time. Speed of transformation is too slow in the pearlite range for the application of either isothermal or continuous cooling annealing. This steel can only be annealed, therefore, by the prolonged tempering treatment, referred to as sub-critical annealing.

Summarising, it can be said a compromise is necessary in selecting the sub-critical temperature to soften both the case and the core, since if the most suitable temperature below the lower critical is used for the core, transformation is slow in the case.

With eutectoid cases a useful compromise, employing a multiple tempering technique, is to allow most of the transformation to take place in the case at 700° C.  $\pm$  10° C., cool to atmospheric temperature, and reheat to 650° C.  $\pm$  10° C., at which transformation of the case is completed and the core softened.

With hypereutectoid cases cooled fairly rapidly from carburising, it is necessary to transform the retained austenite prior to its sub-critical annealing. This is more effectively done by normalising at 750° C., but this normalise can be omitted if slowly cooled hypereutectoid cases are being considered.

#### **Recommended Procedures**

The recommended procedure would therefore be:—

##### *With Hypereutectoid Cases*

- (1) After carburising, air cool carburising box to room temperature.
- (2) (a) *Preferable.*—Unload box and heat components in a neutral salt bath to 750° C.  $\pm$  10° C., until the components are uniformly heated: soak for thirty minutes at temperature, then remove from the salt bath and cool in free circulating air; or  
(b) *Alternative.*—Leave components in carburising box with compound. Heat uniformly to 750° C.  $\pm$  10° C. and soak for 30 minutes at temperature, then remove boxes from furnace and air cool to room temperature.
- (3) When cool, pack components in a suitable container with clean cast iron borings or charcoal, heat uniformly to 700° C.  $\pm$  10° C., and soak for 3 hours; then remove container from the furnace and air cool in container.
- (4) When cool, reheat container uniformly to 650° C.  $\pm$  10° C. and soak at temperature for 3 hours, then remove container from the furnace and air cool in container.
- (5) When cool, remove components.

##### *With Eutectoid Cases*

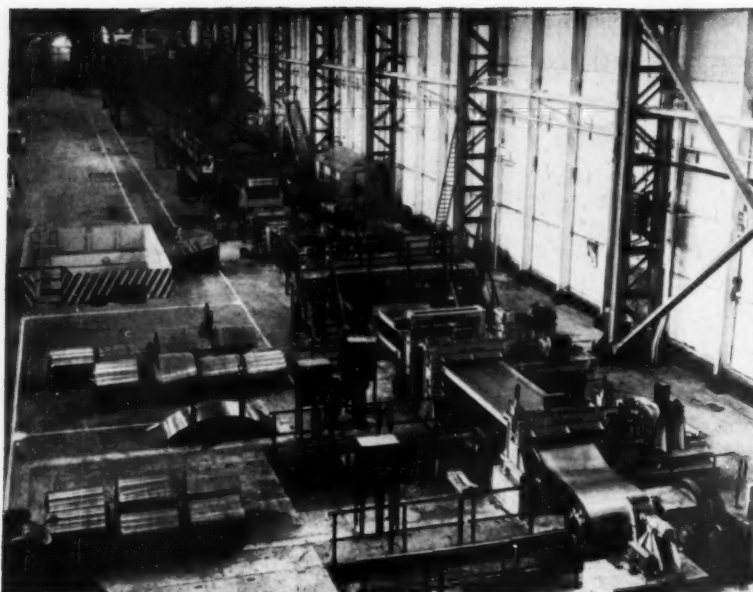
The normalising treatment can be omitted with eutectoid cases. It is only necessary to follow instruction 3 to 5.

#### **Acknowledgments**

The author wishes to thank Messrs. Joseph Lucas, Ltd., for permission to publish this paper, and Mr. E. Mitchell, for his generous and invaluable counsel.

#### REFERENCE

- 1 Atlas of Isothermal Transformation Diagrams of B.S.En. steels. The Iron and Steel Institute Special Report No. 56.



General view of the line from the entry end.

# Continuous Galvanizing of Steel Strip

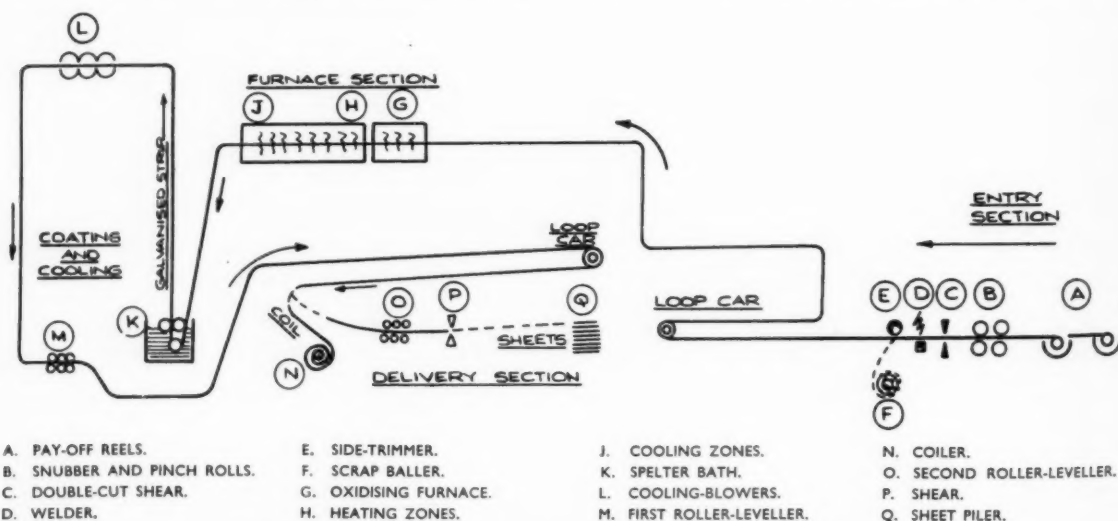
Armco-Sendzimir Line  
Installed at  
Ebbw Vale

**P**RODUCTION early this year of the first Speltafast galvanized sheets at the Ebbw Vale works of Richard Thomas and Baldwins, Ltd., marked the culmination of several years of planning, preparation, installation and testing, and gave the company a new brand-name to add to its already wide range of flat-rolled and coated steel products.

Built at a cost approaching £2,000,000, the new Armco-Sendzimir galvanizing line at Ebbw Vale represents, in part at any rate, the steel industry's reply to the challenge of competitive materials which gained a foothold in established markets during the war, when the output of galvanized sheets was limited by a shortage of zinc. The importance of the new plant lies not only in

its efficiency as a production unit, but also in the improvement in product quality. With conventional galvanizing processes, whereby the steel sheets are treated in separate processes before being passed through a flux and a zinc bath, the main drawbacks as far as product quality is concerned are brittleness and unevenness of coating, and the lack of ductility in the finished sheet.

In the Armco-Sendzimir process, the old-established cleaning techniques involving pickling in sulphuric acid and fluxing are replaced by carefully controlled oxidation and reduction with simultaneous annealing—to produce a surface which gives instantaneous bonding between the steel base and the molten zinc. The absence of any conventional flux allows the addition to the spelter bath



Diagrammatic sketch showing the general arrangement of the line.

of elements such as aluminium, which prevent or minimise the formation of brittle alloy layer, so ensuring that the coating does not flake. In consequence, Speltafast offers a high degree of workability: it is ideal for all seaming and lock forming operations, and for stamping and drawing. Furthermore, the high degree of uniformity of coating thickness ensures satisfactory corrosion behaviour, which can be enhanced by chromating and/or oiling.

### Entry Section

With an overall length of about 700 ft., the new line comprises five main sections—entry, furnace, coating, cooling, and delivery. In the entry section, coils of cold rolled strip are loaded on to the alternative pay-off reels, where back tension is applied by means of air operated water cooled brakes. The pay-off reels are of the overhung expanding drum type, with traversing and elevating coil carriages, and are adaptable for 20 in., 24 in., and 30 in. diameter coils. A.C. drives are used to thread the leading end of the coil through the double-cut shears, where the entry and trailing ends are cropped in preparation for welding. This operation is carried out in a spot welding unit capable of joining mild steel strips of 50 in. maximum width having thicknesses in the range 0.0095–0.078 in.

From the welder, a pair of pinch rolls feed the strip into a looping pit with electronic loop control, and another pair of pinch rolls pulls the strip from the pit through the side trimmer, which is of the overhung driven knife type, using 11 in. diameter by  $1\frac{1}{2}$  in. thick double-edge reversible knives of tool steel. Immediately following is a burr masher to smooth away any burr left by the cutters, and a scrap baller which coils the side scrap on to a driven mandrel. The strip then passes into a second looping pit, from which it is taken round a tension bridle which feeds into the entry loop. This is a horizontal loop, the coil passing round a roll



Strip entering the oxidising furnace.



Operator skimming the spelter bath: the galvanized strip is seen leaving the bath and travelling up to the cooling blowers.

mounted on a loop car, and then over a fixed roll, the loop car moving along a track to accumulate strip to enable the main furnace section to continue whilst the entry section is stopped and started during coil changing.

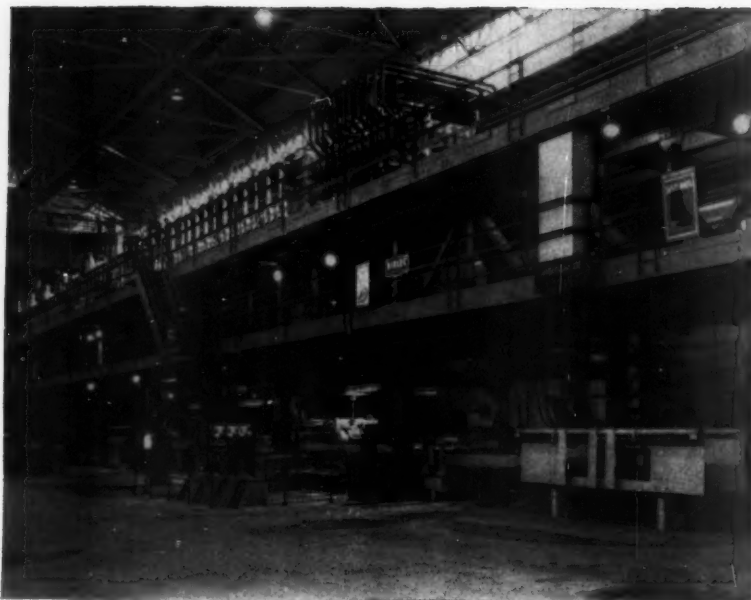
### Furnace Section

The strip is pulled out of the entry loop by means of a further pair of pinch rolls, which feed into a speed balancing loop, where the tension of the hot strip in the furnace is controlled by means of a weighted dancer roll. The strip then passes into the first section of the furnace, which is flame heated, and which serves to oxidise the strip surface and to burn off any rolling oil or other contamination. From the flame heater the strip passes into the reducing section, heated by gas-fired radiant tubes, which is controlled at 1,800–1,850° F. (980–1,010° C.) to give a strip temperature of 1,550° F. (845° C.) for annealing, or 1,750° F. (950° C.) for normalising. Strip temperature is controlled by the speed of the strip, the plant being designed to deal with strip up to 48 in. wide, and to give an output of 7 tons/hr., based on 30 in. wide material in thicknesses between 0.0095 and 0.078 in., over the full range of speeds from 30 to 250 ft./min. The strip emerging from the reducing section has a matt surface suitable for galvanizing, but its temperature has to be adjusted in a cooling section before it enters the galvanizing bath.

Coke oven gas, with a gross calorific value of 500 B.Th.U./cu. ft., is used for heating, the flame heater taking 18,000 cu. ft./hr. and the reducing furnace 21,000 cu. ft./hr.

The exit end of the furnace takes the form of a snout which dips below the level of the molten zinc in the galvanizing pot. Throughout the line, from the entrance to the reducing section to the surface of the zinc bath, a protective atmosphere of dissociated ammonia is





Delivery section of the line with the furnaces above.

supplied to all chambers from one of two generators. Each of these units is capable of supplying 2,000 cu. ft./hr. of cracked ammonia during normal operation.

#### Coating Section

The temperature of the zinc in the galvanizing bath is 835–870° F. (445–465° C.) and the strip should arrive at the metal surface with a temperature of 850–885° F. (455–475° C.). The bath is of Armco design, fabricated from special fire-box steel for the side plates and Armco ingot iron for the bottom plate. Because of the rapidity of the coating action with strip prepared in this way, the time of travel through the bath is short, and the bath is comparatively small—8 ft. 3 in. wide, by 7 ft. 3 in. long, by 6 ft. 1 in. deep. Furthermore, dressing is necessary only once in three months, as compared with once a week in the case of the earlier processes. The bath temperature is normally maintained by the heat of the incoming strip, but electric heating elements are provided for initial melting, and for maintaining the temperature when light gauge strip is being coated.

A submerged idling or pot roll serves to guide the strip through the bath. After passing round this roll, it travels vertically upwards through the driven 10 in. diameter alloy steel coating rolls, which regulate the weight and uniformity of the coating. Provision is made for submerging the coating rolls in the spelter during any down time.

#### Cooling and Delivery Sections

The strip travels vertically from the coating machine to allow sufficient time for the formation of spangle before it passes horizontally through a final cooling section; being drawn through by a pair of pinch rolls, from which it passes downwards to a 2½ in. leveller at floor level. The leveller has 21 2½ in. work rolls—11 top and 10 bottom—and 69 back-up rolls—36 top and 33 bottom; it is used to level for flatness, and also put as much work as possible into the strip, to give the necessary

degree of temper to the material, in view of the fact that it is in a dead-soft condition as a result of the procedure for cleaning and galvanizing.

From the leveller, the galvanized strip passes beneath the spelter bath to a tension bridge, via an exit loop car similar to the entry loop car referred to earlier. The tension bridge provides the necessary back tension when recoiling, and is equipped with a pinch roll unit for threading. The shear is of the under driven down-cut type, equipped with a clutch-trip mechanism.

Instead of recoiling, the strip may be passed through a further pair of pinchrolls and a looping pit into a type 541 Halden rocker shear, with a type 51 levelling stand, capable of shearing at speeds up to 350 ft./min.

From the shear the sheets pass through a second roller leveller—similar to the first, but with 1½ in. work and back-uprolls—and thence to an inspection conveyor for selecting primes and rejects, the latter being diverted on to a reject conveyor. In the primes line is a retractable

four-roll oiling machine for use where required. The piler at the end of the prime conveyor line consists of a 20 ft. diameter turntable, together with adjustable side guides and end stop. These are so arranged that when a maximum pack has been piled on to the bogie, a 180° turn of the turntable brings an empty bogie into position for piling to be resumed. Sheets may be packed and despatched in the flat form, or they may be passed on to the corrugating line.



Prime galvanized sheets being stacked at the delivery end of the line.

## Electrical Equipment

In all, a total of 19 Ward Leonard D.C. drives are used, the line being divided into three sections, i.e. entry, furnace, and exit sections. The drives of each section are speed matched, but the sections may vary with respect to each other by paying strip into or taking it out of the horizontal loops by means of the loop cars. With the exception of the classified section, which handles sheets and requires less critical speed control, each Ward Leonard drive is supplied from its own generator. The generators of each group have their fields supplied from a variable voltage exciter, which is in turn excited through a motorised rheostat which sets the section speed. In order to maintain the correct speed relationship between drives in all three sections, and to ease the duty imposed on the automatic control systems, every drive has an IR compensation acting through its generator, and so giving a uniform regulation irrespective of Ward Leonard voltage variation.

The extent of the control gear needed for the 19 Ward Leonard drives, the 75 constant speed A.C. drives, and 900 kVA. of the furnace resistance heaters can be gauged from the illustration, which shows part of the control room. Some 300 ft. of flat-back control and switchboards together with magnetic amplifiers, electronic amplifiers, and motorised rheostats are included with 750 kW. of rectifiers for general service on the galvanizing line. Full control of the line is provided by push-button and control switch operation on the 4 main desks, 22 control cabinets, and numerous local push-button stations. The control desks and cabinets have stainless steel top and front sheets, respectively. A loud-



General view of the main control room.

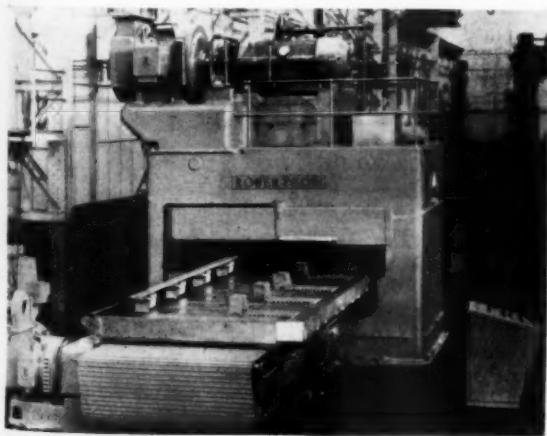
speaker system provides intercommunication between the various control points.

### Suppliers

The main contractor for the line was The Head Wrightson Machine Co., Ltd., Middlesbrough, the whole of the furnace equipment—flame cleaning, annealing and galvanizing furnaces, together with the furnace atmosphere generating equipment—being sub-contracted to Birlec, Ltd. The complete electrical equipment for the project was supplied by The English Electric Co., Ltd., partly directly and partly through a sub-contract from Head Wrightson.

## Ingot Milling Machine for America

THE ENGLISH ELECTRIC COMPANY has recently supplied the complete electrical equipment for a large ingot



milling machine manufactured by W. H. A. Robertson & Co., Ltd., and ordered by the American Brass Company for its plant at Terre Haute, Indiana, U.S.A.

The machine will be used for milling the faces of aluminium and alloy ingots up to a size of 60 in. wide by 12 in. high by 120 in. long, and will remove imperfections from the cast ingots before they are rolled into strip and subsequently into foil. If these imperfections are not removed they show up as serious faults after rolling the material to the finished thickness.

Electrical equipment includes a 200 h.p. D.C. motor driving the milling cutter and a 6 h.p. D.C. motor driving the ingot carriage, both supplied from a Ward-Leonard generator set driven by a 265 h.p. A.C. motor. The cutter can be run at any desired speed from 2,000 to 4,000 ft./min. Ingot carriage forward speed is variable with a fast return speed, the cycle of operation being completely automatic. Control and operation of these drives is by push buttons and control switches on a desk adjacent to the milling machine. A contactor panel and various auxiliary drives were also supplied.

# Heat Treatment and Cleaning in Wire Production

## With Particular Reference to Darwins' New Plant

By Ernest Hague

*North East Area Manager, Electric Resistance Furnace Co. Ltd.*

**I**N the production of steel wire, heat treatment operations are carried out at various stages to condition the material for further drawing operations, or to give it the required final properties. The treatments used include the usual annealing, normalising and hardening operations, which involve heating to a temperature above the upper critical temperature, followed, respectively, by furnace cooling, air cooling, or quenching in oil or water: hardening is normally followed by a tempering operation. There are additionally a number of specialised treatments, such as spheroidising and patenting.

Spheroidising is normally applied to high carbon material for the purpose of obtaining maximum softness by producing a uniformly distributed spheroidal condition of the carbide. When applied to wire or rod, for the purpose of facilitating subsequent drawing, provision may be made for air or air and steam, to be admitted to the furnace to promote scaling of the material, and so remove surface imperfections and surface decarburisation. For this operation to be carried out satisfactorily, of course, it is necessary for the rate of scaling to be greater than the rate of decarburisation. The scale is subsequently removed, either mechanically or by immersion in acid. The wire or rod is then pickled (when necessary), limed, and baked at approximately 200° C. The lime counteracts

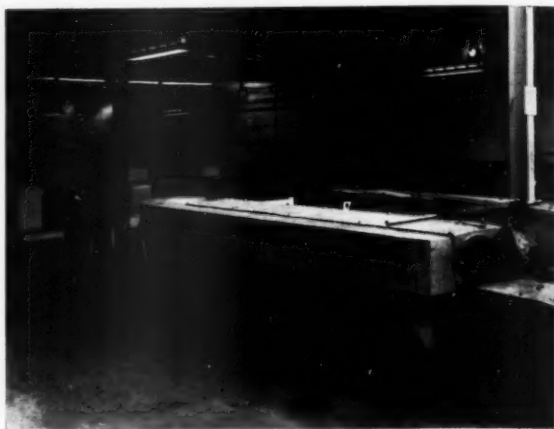


Fig. 1.—Quenchbath of the immersion heater type for use in patenting.

the effects of the acid used previously, and holds the lubricant for the subsequent drawing operation.

Patenting is a treatment widely used in the production of wire for ropes and for manufacture into springs. The purpose of patenting is to produce a structure which enables high carbon steel wire to be drawn many times without intermediate treatment. It also enhances the physical properties, resulting in a very high tensile strength in the finished condition. The treatment involves heating the wire to 950°–1050° C., and maintaining it at this temperature for some time. After soaking, the wire may be cooled in air or quenched in molten salt or lead controlled at a suitable temperature. Fig. 1 shows a typical quench bath of the immersion heater type.

As Darwins Bright Steels, Ltd., are not intending to produce patented wire, the installation at Kingfield Works does not feature any furnace for this purpose. Some very large patenting furnaces are in existence, however, including one supplied by the author's company which has a length of 90 ft.: 32 wires are run in one layer through this unit. A three furnace installation is shown in Fig. 2, the furnace at the right-hand side being used for continuous patenting and galvanizing. A protective atmosphere obtained by processing raw town's gas is fed into the heating chamber to



Fig. 2.—General view of a three-furnace patenting installation at Coatbridge.



prevent scaling of the wire, which, after leaving the furnace is allowed to cool before passing into the acid cleaning tanks and finally the galvanizing bath. The town's gas atmosphere plant is sited against the right-hand wall.

The process of sub-critical annealing, which normally follows the drawing operation, involves heating the work in either a "dry" furnace or a salt bath to a temperature below the critical range, so as to condition the material for further drawing.

### Kingfield Works Plant

#### Heat Treatment Bay

A general view of the heat treatment bay at the Kingfield Works of Darwins Bright Steels, Ltd., is shown in Fig. 3. The plant includes five electric furnaces and one gas-fired furnace, together with the usual ancillary equipment.

The furnace seen at the far end in Fig. 3 is an electrically heated spheroidising unit of the vertical cylindrical forced-air type, rated at 350 kW., controlled in three zones, and designed for use at a maximum working temperature of 800° C. The furnace has working dimensions of 7 ft. 6 in. diameter by 8 ft. deep, and is capable of accommodating four stacks of 30 in. diameter coils, or three stacks of 38 in. diameter coils, the average weight of the charge being 3 tons net.

The lining of the furnace body is of 4½ in. thick refractory brickwork of interlocked construction, and between the lining and the external mild steel casing there are 12 in. of heat insulating material. An inner cylindrical baffle of heat resisting steel is provided to enclose the charge and to form an air duct which, together with the air circulating arrangements in the lid, ensures that air is rapidly and uniformly circulated over the charge and the heating elements in turn. As will be seen from Fig. 4, there is a massive heat insulated lid equipped with electrically operated lifting and traversing motions, controlled by push buttons mounted on the switchgear cubicle. A powerful belt-driven fan is fitted in the lid.

This unit is used for various treatments, including spheroidising, open annealing and sub-critical annealing, details of which are as follows :—

- In a typical spheroidising cycle, the charge is heated to 800° C., soaked for 2 hours, cooled to 720° C., soaked for 4 hours, cooled to 550° C., and then removed from the furnace. The total cycle is of the order of 20–24 hours.
- In open annealing, the charge is heated to 760° C., soaked, and cooled in the furnace to 550°–680° C., the lower temperature being preferred.
- In sub-critical annealing, the work is heated to 700°–720° C., soaked, and cooled in the furnace to 550° C., and then discharged.

Next to the spheroidising furnace is the electrically heated pit pot furnace shown in Fig. 5, which is rated at 175 kW., and is suitable for use at temperatures up to 900° C. It has a lining of 3 in. thick high alumina firebricks, specially moulded to support the heating elements, and a 9 in. thickness of insulation is provided. The



Fig. 3.—General view of the heat treatment plant at Darwins' Kingfield Works.

furnace is equipped with three gas-tight transportable pots, each of which is designed to hold a stack of coils 33 in. maximum diameter and 7 ft. 6 in. high, supported on a base plate suspended from the plug lid by means of removable nickel-chromium straps. The assembly is placed in a gas-tight container, clamped to the lid by means of quick release bolts. Each lid is fitted with a fan to circulate the atmosphere in the container and so ensure rapid and uniform heating and cooling of the charge.

This equipment has been installed to carry out bright and open annealing of carbon steels and clean annealing of high speed steel. Details of typical treatments are given below :—

- In the bright or clean annealing of carbon steels, the charge is heated to 700°–800° C., soaked for approximately 3 hours and cooled to below 100° C. before being removed from the pots. The protec-

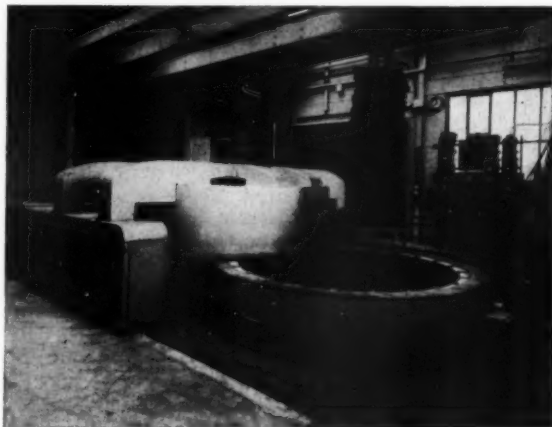


Fig. 4.—Electrically heated spheroidising furnace showing method of roof removal.

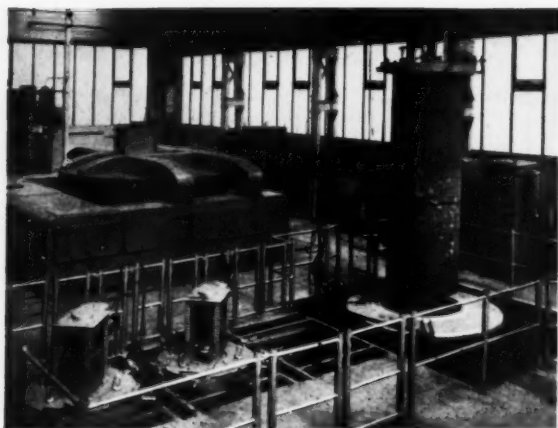


Fig. 5.—Pit pot furnace showing container being lowered into the furnace chamber.

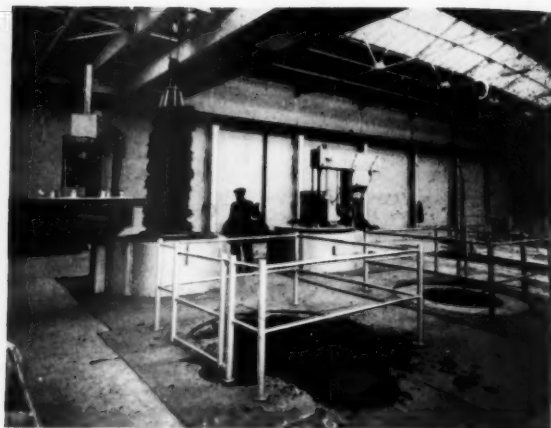


Fig. 6.—Two pit type furnaces with quenching tanks in the foreground.

tive atmosphere used is obtained by processing raw town's gas in a special plant.

- (b) Open annealing (i.e. without a protective atmosphere) of soap-drawn carbon steels is carried out at 700°–800° C. A "flashing" operation is incorporated, the purpose of which is to condition the surface of the material so that it can be readily and satisfactorily cleaned. The pot containing the heated charge is transferred to a cooling position, where the envelope is disconnected from the lid. The lid supporting the charge is raised 2–6 in. from the gas-tight envelope, thus allowing the air to enter. The volatile solvents rapidly burn away and at the same time a very light loose scale is formed on the work. After a short time (30–60 sec.) the lid is lowered back on to the envelope and the charge allowed to cool in the normal way. If the "flashing" operation were not adopted, it would be extremely difficult to remove the sooty deposit left by the drawing lubricant.
- (c) In clean annealing of high speed steel, the material is heated to 900° C., in the protective atmosphere soaked for 2 hours, allowed to cool to 640° C., soaked for 3 hours, and cooled to as near room temperature as possible before being removed from the container.

The electric pit type vertical cylindrical furnaces shown in Fig. 6 have pneumatically operating lid-lifting mechanisms, the lids being fitted with air circulating fans. Each furnace is rated at 120 kW., is designed to accommodate a stack of coils 32 in. outside diameter and 8 ft. deep, and is suitable for use at temperatures up to 950° C. The high alumina lining is 3 in. thick and is provided with supports for the heating elements. There is a 10½ in. thickness of heat insulating brickwork between the refractory lining and the mild steel outer casing. These furnaces are used for hardening, tempering, normalising and, if required, annealing treatments.

All the foregoing furnaces were supplied by Electric Resistance Furnace Co., Ltd., and equipped with automatic temperature control instruments by Electroflo Meters Co., Ltd.

A further pit pot type vertical cylindrical furnace in

this bay was originally installed at the works of J. Stead & Co., Ltd. It is a Junkers 80 kW. unit with two-zone control and a maximum operating temperature of 900° C. There are four removable pots, complete with heads, which will take coils of 26 in. maximum diameter, and each pot can be loaded with 10–12 cwt. of work. The furnace is used for annealing, normalising and bright annealing with a protective atmosphere.

The heat treatment bay also houses a gas-fired furnace reconstructed by Fuel Furnaces, Ltd., for annealing coils of wires. The furnace is fired by town's gas through twelve high powered injector type burners which are controlled by a motorised gas valve through Transnitrol anticipatory temperature controllers, of the self-contained direct-deflection type, by Ether, Ltd.

For hardening purposes two quench tanks are provided, one containing oil and the other water. The oil quench tank is provided with a Serck oil cooler and a recirculating pump and motor. Water for the water quench tank, and for other cooling purposes, is gravity fed from an overhead supply tank to which it is returned.

The various units are served by a Riley 2-ton E.O.T. crane, which is floor controlled and has two-speed hoisting.

#### Wire Cleaning Bay

The equipment in this bay is provided for the cleaning or descaling of wire and wire rod coils after treatment. The author's company supplied the electrically heated (immersed electrodes) salt bath for the sodium hydride process, and there is also a gas-fired salt bath for operating the EFCO-Virgo descaling process. Both processes feature rapid and uniform descaling without attack on the base metal and without hydrogen embrittlement.

The sodium hydride process employs molten caustic soda, held at a temperature of approximately 370° C., plus sodium and hydrogen. The bath has a rating of 100 kW., and the working dimensions are approximately 6 ft. 6 in. long × 4 ft. wide × 4 ft. deep. This unit is of the electrode type, similar to that shown in Fig. 7, where the EFCO-Virgo process is being used for descaling nickel-chromium alloy sheets.

At the Kingfield Works, the EFCO-Virgo process is carried out in a gas-heated salt bath fitted with an electrically operated lid. The working dimensions are



Fig. 7.—Electrode type salt bath being used for the EFCO-Virgo descaling of nickel-chromium alloy sheets.

4 ft. long  $\times$  3 ft. wide  $\times$  5 ft. deep, and the bath is normally reserved for descaling nickel-chromium alloys. The process makes use of a patented salt mixture containing activated agents which are oxidising in nature, and the temperature of operation is approximately  $500^{\circ}\text{C}$ .

Situated between the sodium hydride and EFCO-Virgo baths, so that work from either bath can be readily and quickly quenched, is a fully screened water quench tank fitted with pneumatically operated double doors.

The pickling line includes seven tanks, containing, respectively, hot water, sulphuric acid, hydrochloric acid, nitric-hydrofluoric acid, nitric acid, water (spray), and lime. A very efficient fume extraction system of the lip exit type has been provided to remove the fumes from the various tanks.

For the treatment of pickled and limed wire or rod, a 90 kW. Electric Resistance Furnace Co., rod baker, designed to take a 6 ft. long hook and coils of up to 42 in.

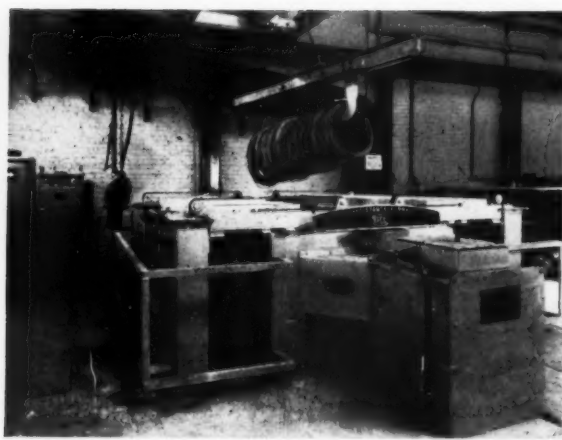


Fig. 8.—Electrically heated rod baking furnace with EFCO-Lindberg Cyclone external air heater units.

outside diameter, is provided. This furnace is of double cased mild steel construction, heavily heat insulated, and provided with a pneumatically operated split lid, as shown in Fig. 8. The specified output of this unit is 2–3 tons of work per hour, but the equipment is capable of giving a substantially greater output if required. The maximum operating temperature is  $400^{\circ}\text{C}$ ., and it is of interest to note that the unit is also used, when available, for preheating material to undergo descaling in either of the salt baths.

The comparatively high output obtainable from this unit is largely due to the method of heating, which includes two EFCO-Lindberg Cyclone external air heater units. With this arrangement, air from the powerful horizontally mounted fan is circulated through a nest of heating elements, thence to the heating chamber and back to the heater unit. Satisfactory baking is achieved in as short a time as ten minutes.

A 1-ton Riley E.O.T. crane, floor controlled, can be used at any point in the bay.

### Light Alloy Associations' Merger

Alar, Ltd., and The Federation of Light Metal Smelters have amalgamated and will continue to carry on their activities under the name of The Association of Light Alloy Refiners and Smelters, Ltd. The members of the Association so formed are: Associated Lead Manufacturers, Ltd.; Atkins "Metals" Ltd.; B.K.L. Alloys, Ltd.; John Cox & Sons (Metals), Ltd.; John Dale, Ltd.; Enfield Rolling Mills (Aluminium), Ltd.; The Eyre Smelting Co., Ltd.; J. Frankel (Aluminium), Ltd.; International Alloys Ltd.; John E. Moore Ltd.; Norton Aluminium Products, Ltd.; T. J. Priestman, Ltd.; Wigley Aluminium, Ltd.; and The Wolverhampton Metal Co., Ltd. The Council of Management consists of: Mr. R. Hahn (Chairman), Dr. J. Jakobi (Vice-Chairman), Mr. B. Endlar, Mr. O. G. Halliwell, Mr. R. Hopkins and Mr. E. W. Nicholls.

The preparation publication and dissemination of technical information previously undertaken by ALAR will be undertaken by the new association, and the Technical Advisory Office at 3 Albemarle Street, London,

W.1., will continue under Mr. F. H. Smith, Technical Officer, to whom all technical enquiries should be made either by letter or telephone (MAYfair 2901). The registered office of the association is at 1 Frederick's Place, Old Jewry, London, E.C.2. (Tel.: MONarch 9988).

### The Warren Spring Laboratory

THE new D.S.I.R., laboratory, now being built at Stevenage, will be called the Warren Spring Laboratory. The name is taken from a lane that used to run across the site on which the laboratory is being built. It will be recalled that the Council for Scientific and Industrial Research have expressed the view that the Warren Spring Laboratory should be a versatile station, free to do work on any subject which becomes important for the nation and which cannot be fitted into the programme of other research bodies. It has already been decided that work will be carried out on air pollution; on the synthesis of oil and chemicals from carbon monoxide and hydrogen; and on mineral processing.



# International Standards Meeting

## Progress at Harrogate in the Metallurgical Field

**T**HE Fourth Plenary Session of the I.S.O.—International Organisation for Standardisation—held in Harrogate from June 9th to 21st, brought to the town nearly 1,000 delegates, each an expert in his own field, from every country which engages in foreign trade. Delegates from the U.K. numbered close on 150, and included leading figures from those industries with a direct interest in the committees meeting at Harrogate. This powerful support in the form of direct participation in the discussions was, moreover, reinforced by the generous financial support of British industry as a whole.

The delegations from other countries were also both large and of high calibre. There were more than 100 representatives from France, 70 from Germany, 50 from Italy, 60 from the U.S., and 30 from Russia. It was specially encouraging to have visitors from some of the smaller countries which are still at an early stage of their development, such as Burma, Turkey and Mexico.

### Technical Committee Reports

All fifteen of the technical committees meeting at Harrogate had their successes to report, and an impressive number of I.S.O. recommendations—which are, in effect, international standards—were brought to completion, or near-completion. The food-containers committee, first to finish its work, set the tone for the rest of the session; in the words of Monsieur Alquier, leader of the French delegation, it had at last “crossed the frontier” after ten years of striving to reach agreement. The nuclear energy committee was able to take its first steps towards the evolution of agreed international standards in this newest of industrial fields. The achievement of the screw threads committee, in accepting one comprehensive series of threads in inch units, in parallel with the metric series, was a fundamental advance; as such it was singled out by the Parliamentary Secretary to the Board of Trade, Mr. F. J. Erroll, when he proposed the toast of I.S.O. at the Session's closing banquet. Brief reports of the progress made in the various technical committees are presented below.

### Steel

Sixty delegates from twenty-three countries attended the meeting of Technical Committee 17—Steel. In the chair was Mr. E. W. Senior, Commercial Director of the British Iron and Steel Federation. This committee's valuable work in securing international agreement on methods of test for steel sheet, strip, wire and tubes was taken a stage further at Harrogate.

Delegates agreed on four proposed methods for the high-temperature testing of steel—a significant advance which will be welcomed by those sections of industry concerned with the production and export of boilers and other high-temperature and high-pressure apparatus operating at temperatures up to 1,000° C. Agreement was also obtained on various methods of mechanical testing of tubes, and this will be of benefit in structural engineering and the fabrication of pressure vessels.

The committee's future programme will include—in

addition to establishing further test methods—consideration of international specifications for the materials themselves.

### Copper and Copper Alloys

Technical Committee 26—Copper and Copper Alloys—held its second meeting in Harrogate under the chairmanship of Mr. Gordon Weston, Technical Director of B.S.I. Forty-three delegates from sixteen countries conferred for four days on items of mutual interest in the field of standardization. They agreed on three proposed I.S.O. recommendations:

- (1) Methods of test for residual (internal) stresses in copper and copper-base alloys (mercurous nitrate test).
- (2) Methods of test for expansion of copper and copper alloy tubing (pin test).
- (3) Classification of raw copper.

Important progress was made in drawing up two basic classifications, one for wrought copper and copper alloys, and the other for cast copper alloys, which include the chemical composition and mechanical properties of the alloys. Delegates gave their preliminary approval to a draft specification for electrolytic copper wire bar, cakes, slabs, billets, ingots and ingot bars. This specification, together with further methods of mechanical test will be sent to the member-countries of this committee for their approval or comments.

Among new projects to be tackled by working groups are: tensile test for sheet and strip of thickness less than 0.5 mm; tensile test for wire of diameter less than 5 mm; tensile test for tubes; wrapping test for tubes; reversed bend test for sheet and wire; simple torsion test; and flattening test for tubes.

### Solid Mineral Fuels

Technical Committee 27—Solid Mineral Fuels—met for five days under the chairmanship of Mr. Donald Hicks, Director of Scientific Control at the National Coal Board. Nearly sixty delegates and observers were present from nineteen countries, and the cordial atmosphere which prevailed during the sessions enabled substantial progress to be made.

Delegates reviewed progress made in preparing about forty standard methods for the determination of physical or chemical properties of coal. Of these, fourteen have already been approved as draft I.S.O. recommendations, and as many more will go forward to that stage as a result of the Harrogate meetings.

The meeting decided that the aim of international standardization must be to arrive if possible at a single approved method for each determination, but agreed nevertheless to continue the preparation of drafts for well-established alternative methods, on the understanding that at each future meeting all of these should be reviewed and as many as possible eliminated. It was agreed that for the measurement of certain physical properties of coal and coke the standardization of a range of tests is necessary.



In view of the importance for many countries of the utilization of brown coals and lignites, it was decided to establish a new sub-committee on this subject, with Poland as secretariat.

A draft prepared by another sub-committee of more than three hundred terms and definitions used in coal preparation was accepted as a basis for further discussion and the future programme of work of this sub-committee, which includes methods of tabulating data and expressing results of coal preparation procedures, was endorsed.

#### *Nuclear Energy*

The second meeting of Technical Committee 85—Nuclear Energy—brought to Harrogate sixty-eight delegates from seventeen countries (including Russia, the U.S. and Britain), observers from two more, and representatives from six international organisations concerned with nuclear energy. Under the chairmanship of a distinguished industrialist—Mr. Morehead Patterson (Chairman of the American Machine and Foundry Company)—the committee and its three sub-committees held discussions lasting eight days, during which good progress was made towards establishing international standards in this new field.

Sub-committee 1, which is concerned with terminology, definitions, units and symbols, agreed on a tentative first list of more than two hundred concepts which will later be defined in a glossary of nuclear terms—thus enabling the scientists and technicians of different countries more easily to exchange information and remove possible misunderstandings in trading practice. Delegates also agreed on the basic design of a symbol to denote the actual or potential presence of ionizing radiation.

Sub-committee 2, whose province is radiation protection, planned its future work and, more particularly, its relations with other relevant international bodies. It adopted as a basis for its activities outline drafts concerned with the indirect contamination of individuals, and radiation detectors.

Sub-committee 3, whose chairman is Mr. F. R. Farmer of the U.K. Atomic Energy Authority, deals with reactor safety. Delegates defined the extent of the committee's interest in radiation measurements, health records and effluent discharge, bearing in mind the concern in these same subjects of such organizations as the International Commission on Radiological Protection and International Atomic Energy Agency. The sub-committee agreed that work on potentially critical accumulations of material connected with processes other than reactor operation should also be undertaken at the appropriate time. In planning its future activities, it became clear that the sub-committee would need, before it could begin drafting recommendations, to collect and collate the great mass of documentation now becoming available on the subject of reactor safety.

A fourth sub-committee with Poland holding the secretariat was established; it will be concerned with radioisotopes. The strong British delegation at the Harrogate meetings was led by Mr. Gordon Weston (B.S.I.'s Technical Director) and included experts from the U.K. Atomic Energy Authority, the Nuclear Energy Trade Association's Conference and the Ministry of Labour.

#### *Cast Iron*

The object of Technical Committee 25—Cast Iron—is to secure international agreement on standards for

foundry pig iron and cast iron, particular attention being paid to the co-ordination of nomenclature, definitions and methods of test.

At Harrogate delegates brought to virtual completion a recommendation on the tensile testing of grey cast iron which will enable manufacturers and users in any part of the world to compare this material on a uniform basis. The committee also reached agreement on a method for testing the hardness of grey cast iron. A useful preparatory discussion was held on international standards for malleable cast iron and spheroidal and nodular graphite cast iron. It was agreed that work on impact testing being carried out by the International Committee for Testing Cast Iron should be continued.

Because of the indisposition of Dr. J. G. Pearce (Director of the British Cast Iron Research Association) the chair was taken by Mr. R. McKinstry of B.S.I.'s technical secretariat.

#### *Light Metals*

Technical Committee 79—Light Metals and their Alloys—met under the chairmanship of Monsieur J. Duval, Technical Director of the French Standards Association. This three-year-old committee has, in the interests of easier world trading (chiefly to avoid misconceptions between buyer and seller), sought agreement on chemical composition and mechanical testing of aluminium and magnesium and their alloys. The committee has prepared recommendations relating to magnesium ingots and magnesium alloy ingots and castings; other recommendations for pure aluminium, aluminium alloy castings, and tensile and hardness testing of light alloys are also at an advanced stage.

At Harrogate fifty-two delegates from fourteen countries reached agreement on international standards covering: (1) composition of magnesium-zirconium alloy castings; (2) compositions of four additional aluminium alloy castings; (3) composition of wrought aluminium and aluminium alloys; (4) unalloyed magnesium conventionally defined as 99.95.

#### *Certification Marks*

Many overseas standards bodies now operate certification marks—similar to B.S.I.'s "Kite-mark" scheme—to indicate that a product conforms with national standards. Technical Committee 73—Marks Indicating Conformity with Standards—was accordingly set up to investigate the practice of different countries in this respect with the object of achieving some degree of uniformity in the principles involved. This committee held its fourth meeting at Harrogate, under the chairmanship of Mr. J. Birlé, Director-General of the French Standards Association.

The committee agreed on the principles applicable to the operation of marks indicating conformity with standards. This difficult question had been considered by the committee since its first meeting. It will now form the subject of an I.S.O. recommendation to be published in the near future. The committee examined the question of informative labelling, aiming to give to the consumer useful technical information on the products purchased, by means of appropriate labels. General agreement was reached on the broad principles on which informative labelling should be based. The committee also considered the possibility for a product made in one country to bear the standards marks of other countries, and it was agreed to study carefully this form of international collaboration.

# NEWS AND ANNOUNCEMENTS

## British Engineering Display at 1959 Canadian Show

In conjunction with the Board of Trade, the Birmingham Engineering Centre are organising a substantial British engineering exhibit at the National Industrial Production Show of Canada to be held in Toronto from May 4th to 8th, 1959. This Exhibition, one of the leading specialist industrial shows in Canada, is held every two years and receives widespread support from Canadian, American, European and British firms. Experience increasingly shows that participation in specialised exhibitions is the most effective method of display on the North American continent.

The Board of Trade's decision to mount a prestige display and the joining of forces with the Birmingham Engineering Centre to organise a separate British participation is an outcome of the Government's desire to exploit all possible means of expanding trade with Canada. The atmosphere created by the visit of the Canadian Trade Mission to Britain last year makes the opportunity particularly propitious.

The National Industrial Production Show will be held in the Industrial Pavilion at the Exhibition Park in Toronto. Although the Exhibition follows accepted North American custom in lasting for the comparatively short period of five days, it does provide a genuine sales opportunity for manufacturers of production engineering equipment—automation devices, tools, instruments, metals, plastics, woodworking machinery, hydraulic controls, and equipment for materials handling, welding, drafting, heat treatment, plant maintenance, paint spraying, foundrywork, compressed air and power production, lubrication and accident prevention. Firms interested are invited to apply for further details to Mr. A. J. Cox, General Manager, Birmingham Engineering Centre, Stephenson Place, Birmingham, 2.

## Brinsworth Cold Rolling Plant

STEEL, PEECH AND TOZER, a branch of The United Steel Cos., Ltd., are to spend over £1½ million on the installation of a cold rolling mill and ancillary equipment adjacent to their Brinsworth continuous medium width hot strip mill. The new plant is planned to be in operation in two years' time.

The Brinsworth mill, completed last autumn, is the only mill of its kind in the country and is engaged in the continuous production of thin steel strip to 18 in. wide. The bulk of its output is at present supplied to customers in the hot rolled condition, but when the new cold mill comes into service, up to 2,000 tons of steel a week will receive a cold reduction after hot rolling.

After pickling, coils of hot rolled strip will be transferred to a tandem cold rolling mill and then annealed in either of two continuous annealing furnaces, each with a capacity of five tons per hour and fired by coke oven gas. The strip will then be rolled in a skin pass mill to improve the metallurgical properties after the annealing process and to impart a good surface finish. It will be slit to the required width in one of a number of slitting machines. The mill will be capable of cold rolling strip

up to 18 in. wide to thicknesses from 0.25 in. to 0.010 in. Although able to deal with all qualities of steel, it will be primarily employed on the cold rolling of carbon steels.

The existing cold rolling department at Steel, Peech and Tozer, which produces narrow steel strip for the strapping, tube and bicycle industries, will not be affected by this new development.

## B.S.C.R.A. Annual Meeting

At the Annual General Meeting of the British Steel Castings Research Association held in London on 9th July 1958, the Chairman Mr. C. H. KAIN, (Lake & Elliot, Ltd) announced the Council's decision to create the office of Vice-Chairman of the Council and to elect Dr. R. HUNTER (The Clyde Alloy Steel Co., Ltd.) to this position. Mr. Kain also announced the recent retirement of Mr. FRANK ROWE (K. & L. Steelfounders and Engineers, Ltd.) from the Chairmanship of the Finance Committee, and the election of Sir WILLIAM SCOTT, O.B.E. (Jarrow Metal Industries, Ltd.) as his successor. Mr. A. H. CATTON (Catton & Co., Ltd.), Dr. C. J. DADSWELL (English Steel Castings Corporation, Ltd.), Mr. A. B. LLOYD (F. H. Lloyd & Co., Ltd.) and Sir WILLIAM SCOTT, the members of the Council retiring by rotation, were re-elected for a five year term.

The 5th Annual Report of the Association which was adopted at the meeting records continuing growth in all activities, and refers to the need which is already becoming apparent in some sections for extension of the laboratories at East Bank Road, Sheffield, which were opened only a year ago.

## Chemical Research Laboratory Changes

THE Lord President of the Council has approved changes in the functions of the Chemical Research Laboratory proposed by the Council for Scientific and Industrial Research. In addition the name of the Laboratory will be changed to the National Chemical Laboratory. The Laboratory will concentrate its effort on a few objectives, covering only a limited part of the whole field of chemical research, so as to be able to make a real impact on selected problems of national importance, including: (a) problems which are appropriate neither to industrial research laboratories nor to universities, because of the necessity for special facilities, experienced staff and continuity of effort; (b) problems, the solutions of which are of national economic value and have wide general applications to many industries; and (c) problems, the solutions of which are urgently required in connection with the nation's atomic energy programme.

## A.D.A. Publications

THE Aluminium Development Association has recently published the 1958 editions of three of its annual publications. The Directory of Members shows the names and addresses of A.D.A.'s Member companies and indicates the products available from each. The List of Publications has been extended by the inclusion of a

new section named the "Symposium Series"—being the proceedings of symposia arranged by the Association in recent years. The third new booklet is that listing films, film strips and wall charts. Copies of these publications are available on request from the Aluminium Development Association, 33, Grosvenor Street, London W.1.

### Davy-United Plate Mill for Northern Aluminium

AN order worth over £1 million has been placed with Davy and United Engineering Co., Ltd., by Northern Aluminium Co., Ltd. It covers the supply of a new 4-high breaking down and plate finishing mill plant for the company's Rogerstone Works. The equipment has been ordered as part of a £10 million expansion scheme to increase the rolling capacity of the Rogerstone Works from 50,000 to 75,000 tons of aluminium strip and sheet per annum.

The principal unit to be built by Davy-United will be a 38 in. and 60 in.  $\times$  144 in. 4-high rolling mill, which will be the first breaking down mill in the Rogerstone hot strip rolling line, and will also be capable of producing finished heavy and light gauge plate. The mill will be capable of breaking down slab ingots weighing up to approximately 8 tons for plate up to 138 in. wide by  $\frac{1}{2}$  in. minimum thickness. It will be driven by two 4,000 h.p. motors, will have a top rolling speed of nearly 600 ft./min. and will be supplied along with a combined slab and plate shear of hydraulic type and all necessary auxiliary equipment.

Following the trend towards increased use of automation in modern rolling mills, a number of Davy-United instruments will be fitted to the mill to provide means of controlling certain functions of its operation automatically, and to give automatic control on the thickness of the strip rolled. Certain of the instruments will incorporate radioactive isotopes.

### Lead Welding Film

THE techniques of lead welding are demonstrated in a new film which has been made by British Oxygen Gases, Ltd. Although it is intended as a guide to students on basic techniques and their applications, the film also illustrates some of the methods of production. Applications for sheet lead welding in building, plumbing and chemical engineering are reviewed and the early history of jointing is shown.

Demonstrations cover all the basic techniques, including down-hand butt and lap, inclined lap, vertical and horizontal vertical and fillet welding. The student is shown how the change is effected from one technique to another and how the various techniques may be combined to meet fabrication or repair work. Although the gases used for all demonstrations are oxygen and acetylene, the fact that other gas combinations can be used for lead welding is taken into account. The film stresses that the small quantities of gas required for the welding of lead permit the use of low capacity cylinders and thereby increase the portability of equipment. The major safety precautions which should be taken during the setting up of equipment are demonstrated, and the O.W. 17A regulator is shown in use on both large and small cylinders.

This new film is entitled "The Welding of Lead—Sheet" (16 mm, black and white, sound, 800 ft., running

time 22 minutes). It is obtainable on free loan from British Oxygen Gases, Ltd., Sales Technical Service Department, North Circular Road, London, N.W.2.

### Refractories Courses

A COURSE of ten weekly lectures on "Refractories, Their Manufacture, Properties and Applications," has been arranged by the Borough Polytechnic, Borough Road, London, S.E.1. and will commence on Friday, October 10th, 1958, at 7 p.m. The course has been organised to provide a detailed and up-to-date survey of refractories and the refractories industry, and the lecturer is Mr. L. R. Barrett. The syllabus of the course and form of application for enrolment can be obtained from the Secretary of the Borough Polytechnic, to whom the latter should be returned as quickly as possible.

### Titanium Prices

IMPERIAL CHEMICAL INDUSTRIES, LTD., Metals Division, have revised the prices of wrought titanium as follows:—

Product	Size	Cost per pound
Billet	Over 4 in.—18 in. diameter	63s.—64s.
Rod	4 in.—0.25 in. diameter	75s.—112s.
Wire	Under 0.25 in.—0.036 in. diameter	146s.—222s.
Sheet	8 ft. $\times$ 2 ft. $\times$ 0.25 in.—0.10 in. thick	88s.—157s.
Strip	0.048 in.—0.003 in. thick	100s.—350s.
Tube	Representative gauge	300s.
Extrusions		120s.

These prices are for 1,000 lb. lots, as compared with the 10,000 lb. lots on the previous list.

### Personal News

MR. J. T. FALLON, Managing Director of the Incandescent Heat Co., Ltd., was awarded the O.B.E. in the Birthday Honours, for political and public services in Smethwick.

MR. J. C. DRIVER has been appointed Chief Inspector of West Instrument, Ltd.

STANTON INSTRUMENTS, LTD., have appointed Mr. O. Brooks as Sales Representative for Scotland and parts of Northern England.

MR. W. H. EVERARD, Manager of Edgar Allen's Electric Furnace, Tropenas and Heat Treatment Departments, has been appointed Secretary of the Electric Steelmakers' Guild, formed last year to promote progress in the manufacture of steel for commercial purposes in electric melting furnaces, and to encourage exchange of information between members.

WEST INSTRUMENT, LTD., makers of temperature control equipment, announce the appointment of Mr. W. PROUDFOOT as Manchester Area Representative for the Company.

DR. R. WECK, Director of the British Welding Research Association, and Chairman of the Commission on Residual Stresses of the International Institute of Welding, has accepted an invitation to be lecturer for an important "Seminar on Residual Stresses" being sponsored by the American Society for Metals at Cleveland, Ohio, U.S.A., from October 30th to November 1st, 1958.



MR. M. PALFREYMAN, who is engaged in post-graduate research in the Department of Refractories Technology at Sheffield University under a bursary provided by the B.S.C.R.A., has been awarded the Frank Holland Memorial Prize by the University.

THE Board of Trade announce that the EARL OF HALSBURY will retire from the position of Managing Director of the National Research Development Corporation on March 31st, 1959, to take up another appointment. Lord Halsbury was appointed temporary adviser to the Board of Trade in May, 1949, in anticipation of the establishment of the Corporation and his appointment as its first Managing Director was made at the end of June, 1949.

MR. F. FOSTER has been appointed Managing Director of Crompton Parkinson (Stud Welding), Ltd., a recently formed subsidiary company of Crompton Parkinson, Ltd.

MR. J. BEECH, who won the Mappin Medal and Premium at Sheffield University this year, is to join the metallurgical research staff of the British Steel Castings Research Association.

DR. P. RODERICK, Senior Research Metallurgist in charge of laboratories, has been appointed Assistant Chief Metallurgist of the Steel Division of the Steel Co. of Wales, Ltd.

THE following appointments have been made to the newly formed A. E. I. Turbine-Generator Division managed by Metropolitan-Vickers: General Manager and Commercial Manager—MR. R. J. COCHRAN; Chief Mechanical Engineer—DR. W. H. DARLINGTON; Chief Electrical Engineer—MR. W. N. KILNER; Manufacturing Manager (Trafford Park)—MR. R. R. WHYTE; Manufacturing Manager (Larne)—MR. D. R. S. TURNER; and Executive (Rugby)—MR. J. G. BODDY. In the Heavy Plant Division, which also came into operation on July 1st and is managed by B.T.H., the following appointments have been made: General Manager—MR. L. DRUCQUER; Chief Engineer—MR. L. D. ANSCOMBE; Manufacturing Manager—MR. C. W. FURNESS; Commercial Manager—MR. R. M. GRANT; Executive (Manchester)—MR. N. R. D. GURNEY; Manager, Large Electrical Machine Sales—MR. I. A. FERGUSON; Manager, Power Rectifier Sales—MR. P. S. CLAYTON; and Manager, Compressor Sales—MR. J. B. SIDDAWAY.

MR. A. CHEYNEY has been promoted Sales Manager of Acheson Colloids, Ltd., and MR. G. F. HENDERSON, Assistant Sales Manager; MR. T. WINT has been appointed Sales Engineer for North East England. Other Acheson appointments include those of MR. G. J. B. DAVIES as General Manager of Acheson Dispersed Pigments Co., and MR. E. A. SMITH as Assistant Manager, European Operation, for Acheson Industries (Europe), Ltd.

Now that the organisation of the Indian Steelworks Construction Co., Ltd., is fully established, MR. R. J. BARRITT is resigning as Managing Director as from September 1st in order to return to company work. He will, however, be available to the Board of ISCON for consultation. MR. W. S. HINDSON, at present Chief Engineer of the Indian Steelworks Construction Co., Ltd., has been appointed as Managing Director in his place. MR. J. STRONG, Executive Director of British Oxygen Gases, Ltd., has been elected President of the Institute of Welding for 1958-59 in succession to SIR CHARLES

LILLICRAP, K.C.B., M.B.E. MR. A. C. HARTLEY, C.B.E., MR. G. ROBERTS, and MR. E. SEYMOUR-SEMPER have been elected Vice-Presidents.

## Obituary

WE regret to record the death of the following:—

DR. C. H. DESCH, F.R.S., who died on June 19th at the age of 84. Originally trained as a chemist, he soon became interested in the study of metals, and in 1901 was appointed to the staff of the Metallurgy Department at King's College, London, where he remained until 1907. From then until 1920, he was at the Royal Technical College, Glasgow, first as a lecturer and later as Professor of Metallurgy, a position which he resigned in order to accept an appointment to the Chair of Metallurgy at Sheffield, in succession to Professor Arnold. The year 1931 marked the end of Dr. Desch's academic career, for it was then that he succeeded Dr. Rosenhain as Superintendent of the Metallurgy Division at the National Physical Laboratory, where he remained until his retirement in 1939. In 1943 he joined the Board of Richard Thomas and Co., Ltd., leaving when the amalgamation with Baldwins, Ltd., took place. Dr. Desch was elected F.R.S. in 1923, and during his career was honoured by several technical institutes, being an Honorary Member of the Société des Ingénieurs Civils de France, of the Institution of Mining and Metallurgy, and of the Iron and Steel Institute. From 1926-28 he was President of the Faraday Society, from 1938-40 of the Institute of Metals, from 1946-48 of the Iron and Steel Institute, and in 1949 of the Newcomen Society.

MR. V. P. DELPORT, Managing Director of Penton Publishing Co., Ltd., for over thirty years, who died on June 3rd. Born in London in 1888, Mr. Delport was educated in Paris and served in the French Army in World War I. He then joined United States Steel Products Co., and from 1921-24 was a consulting engineer. He became Managing Director of Penton in 1924, being European correspondent of *Foundry, Steel* and other journals. Mr. Delport has been European delegate of the American Foundrymen's Society to the International Committee of Foundry Technical Associations, of which he was President in 1937. One of the founders of the Council of Ironfoundry Associations, he was Secretary from 1941-46. He was also a Member of Council of the Institute of British Foundrymen for many years. Mr. Delport was awarded the Gold Medal of the Association Technique de Fonderie, Paris, in 1938, and as recently as May this year, he received the Meritorious Services Medal of the I.B.F.

MR. R. W. SANDERSON, a senior member of the General Electric Company's Research Laboratories at Wembley, who died recently at the age of 58. Mr. Sanderson who was educated at King Edward's School, Birmingham and Birmingham University, joined the staff of the G.E.C. Research Laboratories in 1923. He was responsible for research and development work on primary batteries until 1957, when he took charge of a newly-formed group working on corrosion problems. Mr. Sanderson was a member of the Electrochemical Society of America and of the Institute of Metal Finishing, and served on various B.S.I. Committees; he was permanent chairman of the Battery Committee of the International Electrotechnical Commission.

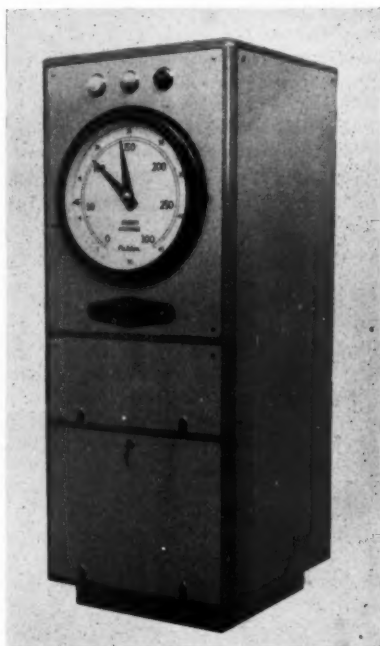


# RECENT DEVELOPMENTS

## MATERIALS : PROCESSES : EQUIPMENT

### Automatic Temperature Scanning Equipment

In many processes it is desirable to keep a check on the temperature at a large number of points, but where the indications serves no useful purpose as long as the temperatures are at the desired values, it would be rather extravagant to have one instrument for each point. The Type B.B.1 automatic temperature scanning equipment, which is a development of Fielden potentiometric scanning systems which have been available to industry for the past five years, overcomes this difficulty by monitoring fifty different points.



The temperature is indicated on a 2 ft. diameter dial around the periphery of which are the point numbers, e.g. 1-50. A motorised scanning switch enables the equipment to examine each point in turn, and a clear Perspex pointer, tipped black, indicates the number of the point under examination. It is possible to have a different set point for each of the fifty variables, the set point being shown by the position of a red pointer which can be adjusted by a small potentiometer under the indicator bezel and in line with the temperature point number.

The actual value of the temperature is shown by the position of a green pointer and the measuring circuit is potentiometric. Thermocouples are used as the detecting elements and the output voltage of the thermocouple is compared with a stable D.C. voltage by means of a self-balancing servo mechanism. All the thermo-

couple leads terminate on a panel at the rear of the equipment, and automatic cold junction compensation is incorporated.

It is appreciated that on a large plant certain of the temperature variables may have to be held to closer tolerance than others and to cope with such a situation the equipment has three tolerance bands which can be adjusted to required values. Any number of temperature points can be allocated to any of these three bands. This will then enable the more important variables to give an alarm should they deviate by more than, say, 2%, others may be set to give an alarm should they deviate by more than, say, 5% and the least important to give an alarm on a deviation of perhaps 10%.

In normal operation the equipment will scan the fifty points in sequence, the red pointer will balance to the desired value and the green pointer will balance to the actual value. If the difference between these pointers is more than the pre-fixed amount for that particular point, then the scanning switch will stop and the signal lamp corresponding to the particular tolerance band will be illuminated. The scanning switch can be re-started either by bringing the temperature to within the pre-fixed tolerance band or by manually switching the scanner to the next point in the sequence.

Manual over-ride is possible by means of a handle provided on the front panel of the instrument and this enables any temperature point to be indicated at will without waiting for the scanner to reach that point in its normal sequence. Push buttons are also provided which will stop and start the scanning switch so that this can be arrested on a particular point for any desired length of time. The speed of scanning is approximately 6 seconds per point and one point can be wired from the constant voltage source in order to check the operation of the equipment.

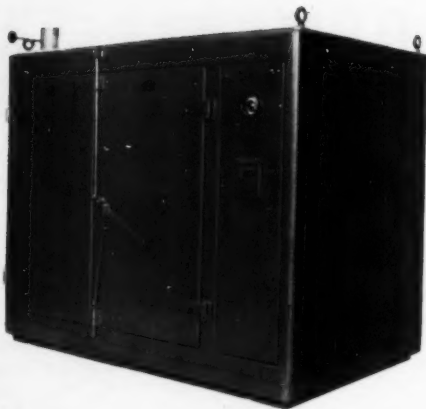
The whole unit is made easily accessible and the electronic chassis are of the plug-in type and are on runners accessible through one of the front panels.

*Fielden Electronics, Ltd., Wythenshawe, Manchester.*

### Electric Oven

BECAUSE of its performance and construction, the electrically heated oven with forced air circulation recently introduced by Hedin, Ltd., has many uses in both production shops and laboratories. Normal temperature control is  $\pm 1\%$  of the operating temperature, up to either 200°C. or 425°C., as required, but straight line control is also available. Each unit is supplied complete with readily accessible gear giving instant visual indication of operation, plus suitable electrical protection. The fan and motor, for instance, are interlocked with the heaters, so that the latter cannot be switched on without the fans. The fans may, however, be run independently.

Forced air circulation is by means of a centrifugal fan, and is continuous throughout the oven and heating chambers: there are about twenty air changes per



minute. A butterfly valve to give controlled air circulation/re-circulation is available, together with various other items such as a vertically lifting door and shelves or trays. A wide variety of sizes is available, with either vertical or horizontal air flow.

*Hedin Ltd., Commerce Estate, South Woodford, London E.18.*

### A New Tool Steel

THE new Osborn high-speed steel, Mushet Special V.G. is a specially balanced tungsten-molybdenum super high-speed steel, containing cobalt for enhanced red-hardness, with greatly increased carbon and vanadium contents to employ to maximum effect the great intrinsic hardness of vanadium carbide. The resulting combination of high hardness, red hardness, great abrasion resistance and a good measure of toughness impart a suitability for all types of cutting operation. It is claimed that a performance surpassing that of normal types of high-speed steel is obtained, particularly in cutting the more abrasive materials and those of high work hardening capacity; tools have a longer life between regrinds and will cut faster. The manufacturers have carried out extensive tests, and have obtained performance details on many materials, including high-speed, stainless, carbon and alloy steels, together with Nimonic alloys. The steel is now available in the form of lathe and planer tools, toolholder bits, etc., as well as in bars and blanks.

*Samuel Osborn & Co., Ltd., Clyde Steel Works, Sheffield, 3.*

### New Surform Tools

FOUR new Surform tools have recently been introduced, all incorporating the distinctive blade, developed by Firth Brown Tools, Ltd., which has a hardened and tempered tool steel blade, set with 500 scientifically angled teeth, and perforated with 500 holes which effectively prevent clogging. The new tools have been designed for jobs which, although commonly encountered, require more precision than can be obtained with a general purpose flat tool.

The Surform block plane (No. 111) has a fine cut blade which gives an excellent performance when used for

quick, one-handed smoothing of edges, and small surface areas, especially in awkward places, whilst the Surform fine-cut file (No. 102) is designed to give a smooth clean cut on mild steel and other tough materials. Of particular value for spot trimming and smoothing metal bodies in the car industry, and in the general building and boat-building industries, is the Surform convex plane (No. 105), which is also a fine cut tool. The surform half-round file (No. 103) gives fast and first class results on concrete surfaces.

The Surform blade gives controlled depth of cut with the minimum pressure. Cuttings pass through the perforations in the blade, so that clogging is impossible—a point of particular interest to users of plastics, which are liable to soften through frictional heat caused by clogging. The tools can be recommended for work with Formica, plastics, plywood and hardwood, where there would normally be danger of splintering, chipping and splitting. These specially shaped tools are also recommended for use on all metals, wood and timber products, plastics, Fibreglass, asbestos, linoleum, cork, leather, ebonite, horn, hoofs and bone.

In tests carried out on Herbert file testing machine, markedly better performance was shown with Surform blades. For example, the standard blade works over 27 times faster on wood and 3 times faster on copper, than a rasp. The fine cut blade works 11 times faster on aluminium than an engineer's rough file.

*Simmonds Aerocessories, Ltd., Treforest, Glamorgan.*

### Electric Resistance Rivet Heating Machines

ALL methods of rivet heating, other than the electric resistance method, waste a considerable amount of heat, and a "warming up" period is required before they can be used. In addition, fuel is consumed whether the rivets are actually being heated or not. The saving in fuel costs and reduction in waiting time with electric resistance heaters is appreciable, especially where the demand for heated rivets is somewhat irregular.



Further advantages of the electric resistance method of heating are: (a) simplicity of operation; (b) the heat is concentrated in the shank, the head of the rivet remaining comparatively cool; (c) rivets being visible while heating, there is less loss due to overheating and burning; (d) the machine requires practically no maintenance, apart from electrode dressing; and (e) there are no fumes or ash.

The design of the new Metrovick range embodies the experience gained in the manufacture of such machines over more than thirty years. In the multi-head machines, separate transformers are used so that each may be set on a different tapping if more than one size of rivet is required simultaneously, and to prevent the loading of one head affecting the heating speeds on the others. A further advantage of this arrangement is that in the rare case of damage to a transformer, one can be removed for repair, and the other head(s) of the machine brought back into immediate production. The transformers are enclosed in fabricated sheet steel cases, on the fronts of which are mounted the electrode holders. The upper electrode of each pair is fixed in an easily pre-set position, according to the average length of rivet being used, while the lower one is spring loaded, enabling it to be drawn away by depression of a pedal for loading and unloading. In order that the machines may be used in semi-exposed positions, the standard range is of drip-proof construction, and lifting eyes are provided for convenience in moving them about the assembly shop.

*Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.*

### Wheel Flange Lubricating Rod

WHEEL flanges and rails wear and cost a great deal to maintain. When a locomotive turns sharp corners or a crane yaws in its travel, the rail and flange grind heavily against one another. This wears the flange and necessitates refacing. When this is carried out a large part of the tread is removed, and with cranes this frequently entails fitting a new tyre.

The Morgan Crucible Company has developed a new method for lubricating the wheel flanges of both trains and travelling cranes, utilising a graphite lubricating rod.—The Morganite Wheel Flange Lubricating Rod—which consists of a soft graphite material encased in a harder carbon tube. The lubricant is applied only to the wheel flanges, and as it is a "solid", it cannot run or "creep" onto the tread and cause skidding. Graphite adheres well to metal surfaces, and rain, dirt or heat do not affect it. The lubricating rod can be carried in a simple holder, which is easy and economical to make and install, and keeps the rod constantly applied to the flange, thus making the lubricant available while the vehicle is in motion.

*The Morgan Crucible Co., Ltd., Battersea Church Road, London, S.W.11.*

### Separating Screen for Barrelling Machine

Now adopted as standard equipment for the Roto-Finish Midget barrelling machine (DW 16-16-2) is a new type of screen tray. This consists of a sheet steel tray, the base of which is perforated with square holes. More



accurate separation of chips from parts can be achieved than is possible with a wire screen, and the stronger construction prevents bending under the weight of chips and parts. Because of the tray shape and the integral construction, parts and chips cannot lodge between the edge of the screen and its support. After separation of the chips from the parts the screen tray serves as a convenient container for the parts. A set of six screen trays with different sizes of screen is provided as standard equipment with each DW 16-16-2 machine.

*Roto-Finish Ltd., Mark Road, Hemel Hempstead, Herts.*

### Pneumatic Multiplying Relay

SHOWN for the first time at the recent I.E. & A. Exhibition, the multiplying relay developed by Sunvic Controls, Ltd., multiplies, divides or extracts the square root of pneumatic signals in the 3-15 lb./sq. in. range. The instrument will, for example, produce an output representing the ratio of two independent process variables such as flows. Its square root facility is invaluable for linearizing the output of an orifice plate flow meter. The actual relay plugs into self-sealing sockets inside the metal cover, which is designed for either wall or back-of-panel mounting. This means that the relay can be inserted after piping is completed and can also be removed at any time without the use of tools and without escape of air.

*Sunvic Controls Ltd., 10 Essex Street, London, W.C.2.*

### Bright Silver Plating Process

BRIGHT silver electro-deposits are desirable for many applications, including both decorative and industrial finishes. To meet this need, the Baker Platinum Division of Engelhard Industries, Ltd., have recently introduced a bright silver plating process embodying a number of interesting features.

Plating is carried out in a high cyanide bath to which

special brighteners have been added, and excellent results are claimed for its use with either Baker "dog bone" or conventional anodes. Uniformly good results can be obtained with current densities ranging from 10 to 40 A./sq. ft., and the throwing power of the solution is said to be excellent. The brighteners are completely stable with no deleterious decomposition products, and organic contaminations can be removed by filtration through activated carbon. Room temperature operation reduces the tendency for carbonate build-up and fumes. The clear water-white solution enables the plater to watch work in the process of being plated, and facilitates recovery of parts falling into the tank accidentally, thus avoiding contamination. The process is non-critical and easily controlled, and bright, highly ductile, hard (V.P.N. 135) deposits can be obtained through a complete range from a flash to a heavy deposit.

*Engelhard Industries, Ltd., Baker Platinum Division,  
52 High Holborn, London, W.C.1.*

### Heavy Duty Lifting Magnet

RAPID MAGNETIC MACHINES, LTD., have developed a powerful lifting magnet to meet the long felt need for equipment suitable for handling material from haphazardly stacked stockpiles. Hitherto, circular pattern magnets have been used, but these are not very effective, since their penetrative qualities are disposed only at the centre pole, which is approximately one-third of the diameter of the magnet.

The new magnet, the Rapid TLM.55.48, is of rectangular form, its powerful impinging field ranging over the entire length of the magnet's operating face, resulting in a substantial increase in pay-load of approximately two and a half times that of a comparable circular type. A typical rectangular magnet 55 in. long  $\times$  48 in. wide, is successfully handling 8-ton lifts of loose  $2\frac{1}{2}$  in. square billets, in the railway sidings of a large works in Manchester. In this instance, the number of men has been reduced from five to two, and there has also been a considerable time reduction in the operation cycle. To facilitate handling, further specially constructed motorised spreader beams can be incorporated, enabling the load to be rotated through 90°.

*Rapid Magnetic Machines, Ltd., Lombard Street,  
Birmingham, 12.*

### Agent for Rapid Drying

A NEW technique for the rapid drying of metal articles has been introduced by I.C.I. Metal parts are treated in trichloroethylene to which has been added a special new additive, Trisec, that ensures freedom from staining even of bright plated and polished parts. It is well known that wet metal articles can readily be dried by immersing them in the vapour of a boiling chlorinated solvent, such as trichloroethylene—the solvent used in most I.C.I. degreasing plants. The moisture film will dry off because, although the boiling point of trichloroethylene (87° C.) is below that of water, a mixture of solvent and water boils at an even lower temperature (73° C.). Vapour degreasing plants can therefore be used for drying small metal articles, even though the evaporation of large drops of water from the surface leaves stains. Owing to the risk of staining, such a method is not suitable for bright plated or other polished surfaces.

With the new I.C.I. technique, the idea of using

trichloroethylene has been retained, but the treatment is in liquor instead of vapour, and to prevent stains forming on the articles, the special additive, Trisec, is mixed with the solvent. Trisec has been specially developed to be effective at moderate temperatures, so that advantage can be taken of the low heating requirements of trichloroethylene. The effect of the additive is to displace the water film on the metal surface by trichloroethylene, which readily evaporates.

The treatment is most effectively carried out in simple equipment similar to a standard LV2 or LV3 I.C.I. degreasing plant, but incorporating a water separator and extra free board above vapour level, and fitted for rim ventilation. One compartment—that containing Trisec—is used for the drying operation and the other for the subsequent rinsing of the dried parts in pure boiling trichloroethylene. This ensures that the articles are not only perfectly dry, but also quite free from grease contamination. The whole process is normally completed in about 1 minute. Any article which can be degreased in an I.C.I. liquor-vapour degreasing plant can be dried by using Trisec, provided that the appropriate type of basket, jig, or other handling equipment is used. As with any drying process, it is necessary to ensure that the work has been well rinsed in clean water before it is introduced into the plant.

*Imperial Chemical Industries, Ltd., Imperial Chemical  
House, Millbank, London, S.W.1.*

### A New Surface Pre-treatment for Metals

JENOLITE, LTD., have recently introduced a new product for the chemical pre-treatment of metals prior to painting. Marketed under the name of Jenocote, this material can be brush applied and it is claimed that it is not affected by climatic conditions, will bond tenaciously to all ferrous and the majority of non-ferrous metals, with particular reference to aluminium and its alloys, and zinc and/or zinc-coated surfaces, and is unaffected by most solvents used in paint formulations. Jenocote solution can be applied to sand- or grit-blasted, or flame de-scaled, hot rolled steel. It can also be applied, with the same degree of success, to cold rolled, close annealed steel.

It is known that after de-rusting ferrous metals by various chemical and mechanical methods, the cleaned surface will rapidly corrode when exposed to even relatively low humidity. To offset this type of rapid corrosion, a further protective measure is necessary, which involves the application of either another protective paint coating, or chemical phosphating solutions, followed by painting. Delay in carrying out any of these processes—which may be unavoidable due to climatic conditions—can have harmful effects on the resistance to subsequent corrosion. The new product has been developed to overcome these limitations of the usual phosphating solutions, and it is claimed that its application to de-scaled, de-rusted, or even lightly rusted steel, will yield excellent corrosion resistance in combination with a protective paint system. Stoving enamels can also be applied to a Jenocote surface and force-dried. Other coatings successfully applied over Jenocote include all types of cellulose, synthetics, enamels, bituminous coatings and epoxy coatings.

*Jenolite, Ltd., 13-17, Rathbone Street, London, W.1.*



# CURRENT LITERATURE

## Book Notices

### HANDBOOK ON NON-DESTRUCTIVE TESTING

Third of a series of three booklets published by the British Welding Research Association, 29 Park Crescent, London, W.1. 7s. 6d.

"MEMORANDUM ON NON-DESTRUCTIVE METHODS FOR THE EXAMINATION OF WELDS," British Welding Research Association booklet T.29/1, is the last in a series of three booklets which form the B.W.R.A.'s handbook of non-destructive testing. The others T.29/2 "Photographic Aspects of Weld Radiography," price 3s. 6d., and T.29/3 "X- and Gamma-Ray Safety Precautions," price 2s., were published in June 1956, and March 1957 respectively. T.29/1 replaces an earlier Memorandum, T.29, published in March 1952. Since then, advances have been obtained by laborious investigations, and the results of these are incorporated in T.29/1. Its main chapter headings are: radiographic methods, ultrasonic and other acoustical methods, magnetic methods, penetrant methods, gas leak method, the proof test or overload test, and semi-destructive methods. There is a glossary of terms in radiography, an appendix showing the defects in welds revealed by various examination methods, and another appendix showing their applicability to the different welded joint forms.

### THE CALCULATIONS OF DEFORMATIONS OF WELDED METAL STRUCTURES

By N. O. Okerblom. A translation from the Russian published by H.M. Stationery Office on behalf of the Department of Scientific and Industrial Research. 15s. net.

WHEN planning the procedure for the fabrication of welded structures, special attention has to be paid to measures designed to ensure the least possible deviations of the finished structure from the design dimensions. This is necessary on grounds of strength and to reduce the amount of time taken up by straightening, trimming, etc. To minimise distortions and departures from the specified design as a result of welding, a quantitative calculation of the deformations produced during different assembly and welding procedures is necessary. These calculations are used as a basis for selecting the most appropriate assembly and welding procedures, and for the design of counter measures, such as counter-distortion, pre-setting, etc., in such a way that their combined effect should balance the welding deformations as nearly as possible.

There is a general theory of welding deformations and stresses from which the latter can be determined theoretically. In industry, however, it is usual to make only a qualitative estimate, based chiefly on trial-and-error methods, guess work and past experience. The main reason for this practice lies in the considerable mathematical effort required for the theoretical determination of these stresses and deformations. A need is felt, therefore, for practical methods enabling engineers in industry and design office to calculate reasonably quickly, and without too much effort, the deformations liable to occur in industrial welding in varying conditions. This book is intended, in a convenient form for engineers, to describe approximate methods for calculating such

deformations. The methods set out in the book are the result of systematic investigations conducted over many years, either by the author or under his supervision, at the Leningrad Polytechnical Institute, the Welding Industry's Central Research Institute, and the Bridge Construction Research Institute, and various other establishments. Results of investigations carried out at the Leningrad Shipbuilding Institute, and of other relevant papers published in the literature have also been used.

The methods of calculation described in this book are based on a general theory of welding deformations and stresses developed by the author and contain practically no empirical relations. They are, therefore, capable of further perfection, development and simplification, and with this in mind, the author has included the theoretical foundations and derivations of the formulae used. Examples illustrating the calculation of deformations of welded structures in different branches of industry are given to help the reader in assimilating the calculations and methods outlined.

## Trade Publications

WE have received from The Morgan Crucible Co., Ltd., a new leaflet dealing with Crusilite, the new non-metallic furnace element, manufactured by the company, which makes electrical heating of furnaces both economic and highly convenient. The great advantage of this form of heating—simplicity of furnace design, cleanliness and absence of flue gases—can now be utilised in all temperature ranges up to 1,500° C. The leaflet gives details of all the different applications and range of sizes.

NORTHERN ALUMINIUM COMPANY's new booklet, "Noral Stress-Relieved Plate," is a brief guide to the thick, high-strength stress-relieved aluminium alloy plate now being made by Northern for the aircraft industry. For much of the new technique of fabricating certain stressed parts of high-performance aircraft by integral construction, the first requirement is high-strength aluminium alloy plate. Besides being of the right composition, and correctly heat-treated to develop full mechanical properties, this plate must have a low level of residual internal stress to ensure freedom from distortion on machining, and must have no undetected internal flaws. The booklet is intended to provide designers with information on the properties, sizes, manufacturing tolerances and inspection standards to which this plate is produced.

The advantages to the aircraft industry of its high strength/weight ratio have led to the rapid development of titanium in recent years. A further important property of the metal is its excellent resistance to many highly-corrosive environments, and William Jessop and Sons, Ltd., have recently issued Information Sheet No. M. 811 dealing with these properties. Specific media dealt with include mineral acids, inorganic salts, organic compounds and gases. There are sections on galvanic corrosion and a comparison of the corrosion properties of titanium and austenitic 18/8 steel containing molybdenum.

THE third issue of *The Forge*, the journal of the Brockhouse Group of Companies, contains an interesting

article on the manufacture of road springs at the modern factory of Richard Berry and Son of West Bromwich. Other features deal with the use of oil firing in the horticultural industry and the new Brockhouse factory at Johannesburg. In a leading article, Mr. J. L. Brockhouse, Chairman and Managing Director, comments on that provocative topic "the right to strike."

AN account of the triple medium direct reader, which has the capacity of two single instruments and the photographic spectrograph combined, is given in the May 1958 issue of the *Hilger Journal*. This instrument has been so designed that one can start with the equivalent of a single instrument and build up to the full-power triple instrument later. A further note in this issue gives information on the use of the medium direct reader in analysing certain types of iron and steel.

THE Incandescent Heat Co., Ltd., have issued a revised leaflet No. V.26A dealing with the Company's standard gas-fired furnaces. These range in size from  $12 \times 12 \times 9$  in., to  $48 \times 36 \times 18$  in., and are designed for carrying out such processes as normalising, annealing, pack carburising, reheating for refining, hardening, tempering etc., within the temperature range  $600^\circ\text{C}.$ – $1,000^\circ\text{C}.$

WE have received from the Cambridge Instrument Co., Ltd., two new publications: the first, List 149/1, deals with the recording accelerometer, suitable for measuring accelerations, decelerations and vibration of mine lifts, cars, aeroplanes, etc.; the 32-page publication, List 163/1, gives abridged specifications of the electrical instruments made by the Company. These include galvanometers, voltmeters, ammeters, wattmeters, oscillographs, bridges, resistances, A.C. sources, etc.

ABSTRACTS of papers presented at the recent Annual Conference of the Institute of Metal Finishing form a particularly interesting section of the June issue of *The Nickel Bulletin*. The subjects range from a study of stress in nickel deposits to determination of their weather-resistance, and variation in properties resulting from ageing of bright-nickel solutions. Items in the section on heat- and corrosion-resisting materials are concerned, *inter alia*, with abnormal grain growth in turbine-blading alloys; the beneficial effect on creep properties of additions of zirconium and boron; continuous rolling of stainless steel; and the resistance of nickel and its alloys to fused sodium hydroxide. Reference is made also to several papers relating to the welding and other characteristics of high-nickel alloys, stainless steels, and 9% nickel steel.

"STEPPING OUT WITH PROGRESS" is the title of a new explanatory leaflet recently published by the Morgan Crucible Co., Ltd. It traces the history and development of the Company, founded over 100 years ago by five Morgan brothers who bought the manufacturing rights of a new process for making crucibles. In every decade there has been an advance to match the technological resources of the Company with the increasing requirements of scientific and industrial progress, marked in the atomic age by the formation of a new company, Nuclear Graphite, Ltd., in association with the A.E.I. John Thomson Nuclear Energy Company.

THE Copper Development Association's quarterly publication *Copper*, maintains in its Summer issue the high standard of presentation set by the first issues. Industrial uses of copper and its alloys are discussed in three articles

dealing, respectively, with the electrolytic tinplate process, papermaking, and shipbuilding. The material featured in the third of the series on copper and its alloys is nickel silver, whose diverse applications range from architecture to electronics. Other articles are concerned with copper for roofing purposes and a revival of brass and copper as decorative media in the home.

RESEARCH AND CONTROL INSTRUMENTS, LTD., the company recently formed to make available to the British market a wide range of electronic equipment gathered from countries all over the world, has produced the first issue of *The R.C.I. Standard*, in which there are a number of interesting articles covering such varied topics as a 5MeV. X-ray unit, electron microscopy, non-destructive testing, and ceramic packed thermocouple wire.

THE extrusion process is such that each particular item of equipment used presents its own peculiar problems to the maker. Hadfields, Ltd., have for many years specialised in the production of extrusion press components, and Publication No. 477 discusses these problems briefly with regard to container assemblies, liners, mandrels, stems and dies.

DURING the past decade, major progress has been made in the development and application of metal-cased bricks. These bricks play an important part in the economics of basic open hearth and electric steelmaking, since the ordinary basic bricks fail by progressive flaking and falling away of the hot face of the refractory. General Refractories, Ltd., have recently issued a brochure giving particulars of the four grades of metal-cased chemically bonded bricks—chromite, chrome-magnesite, magnesite-chrome, and magnesite—made by the company. Besides steelmaking, these bricks are finding increasing applications in the non-ferrous metal and glass industries.

It is occasionally necessary to examine radiographs before they are fully washed and dried. A new Kodak leaflet describes the wet film attachment which enables the wet film in its hanger to be carried from the darkroom and suspended in front of the illuminator without dripping water on the floor or desk. It also protects the illuminator from corrosion.

## Books Received

"Aspects Physico-Chimiques de L'Elaboration Des Metaux." By D. W. Hopkins. 277 pp. inc. index. Paris, 1958. Dunod. 2900 F.

Directory of Opportunities for School Leavers, 1958. With a preface by Sir John Wolfenden, C.B.E. 179 pp. London, Cornmarket Press, Ltd. 8s. 6d. net., by post 9s. 3d.

"The Calculation of Load and Torque in Hot Flat Rolling." By P. M. Cook and A. W. McCrum. 109 pp. London, 1958. The British Iron & Steel Research Association. 65s. or \$9.30.

"The Metallurgy of Vanadium." By W. Rostoker. 185 pp. New York and London, 1958. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 68s. net.

"Practical Microscopy." By L. C. Martin and B. K. Johnson. 3rd Edition. 138 pp. inc. numerous illustrations and index. London and Glasgow, 1958. Blackie and Son, Ltd. 12s. 6d. net.

# LABORATORY METHODS

MECHANICAL • CHEMICAL • PHYSICAL • METALLOGRAPHIC  
INSTRUMENTS AND MATERIALS

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## The Preparation of Tin and Tin Alloys for Micro-Examination

By B. L. Eyre\*

*An account is given of the techniques used at the Tin Research Institute for polishing tin and tin alloys for micro-examination, both in massive form and as coatings. The methods are based on conventional grinding and polishing techniques, using specially selected abrasives and polishing cloths. Diamond abrasives are employed for the major part of the fine polishing. The text is accompanied by photomicrographs which illustrate various aspects of the techniques of polishing and etching.*

**R**ECOMMENDED methods for the preparation of tin and tin alloys prior to examination under the microscope were described in a publication by the Tin Research Institute in 1951.<sup>1</sup> Newer techniques, however, which are less demanding of individual skill, have recently been developed in the metallographic department and are dealt with in this paper.

The preparation of alloys containing tin as a relatively minor addition, as, for example, in bronzes, does not present undue difficulty; however, where tin occurs as a major constituent, considerable problems arise necessitating the use of special techniques. The difficulties encountered in polishing thin tin or tin alloy coatings on relatively harder basis metals, are in general, different from those arising with massive pieces. Therefore, for convenience, the techniques used for massive pieces and for coatings are considered separately.

### Tin and Its Alloys in Massive Form

Tin has wide practical applications both in alloys where it is present as the major constituent, such as solders and whitemetals, and as an alloying addition to other metals, as for example in tin bronzes and aluminium-tin bearing alloys. The most difficult to prepare for micro-examination are those rich in tin. This is due to their extreme softness, thus making it difficult to obtain an unworked surface free from scratches; their low recrystallisation temperature may result in false structures if distortion occurs during polishing. To overcome these difficulties it is therefore necessary to take special precautions during both mounting and polishing.

#### Mounting

Mounting of tin-rich materials should be done at room temperature, because elevated temperatures can cause structural changes, such as precipitation of a second phase from a super-saturated solid solution. Thermo-setting mounting compounds are therefore unsuitable. Specimens can be mounted satisfactorily at room temperature using N.H.P. mounting materials.† It is

TABLE I.—PLATING SOLUTIONS AND CONDITIONS

Type of Bath	Composition	Operating Conditions
Copper Cyanide	Copper cyanide 22.5 g./litre	Temperature 54°-60° C. Current density 10 A./sq. ft.
	Sodium cyanide 30.0 g./litre	
	Sodium carbonate 15.0 g./litre	
	Rochelle salt 60.0 g./litre	
Acid Copper Sulphate	Copper sulphate 202.5 g./litre	Temperature 18° C. Current density 40 A./sq. ft.
	Sulphuric acid 26 ml./litre	
Watts Nickel	Nickel sulphate 240.0 g./litre	Temperature 30°-40° C. Current density 10-100 A./sq. ft. pH 4.5-6.0
	Nickel chloride 46.0 g./litre	
	Boric acid 30.0 g./litre	

recommended that mounting should be done under pressure to obtain a non-porous mount. However, if the specimen is very fragile, mounting can be done without pressure, although this takes longer and gives a porous but still serviceable mount.

Tin bronzes, aluminium-tin alloys and other tin-containing alloys having a relatively high recrystallisation temperature, can be mounted using one of the thermo-setting mounting compounds. However, since the N.H.P. mounting compound is generally satisfactory, it is used for all specimens at the Tin Research Institute. The N.H.P. compound is soluble in acetone and, consequently, industrial methylated spirit is generally used for drying specimens.

When it is required to examine the edges of a specimen, a supporting layer is electrodeposited on to the surface before mounting. This procedure is particularly useful in the preparation of alloys which are harder than the mounting medium and therefore prone to bevelling at the edges.

Before electroplating, the specimen must be solvent degreased and then cathodically cleaned in 5% trisodium phosphate solution. For all samples except those which are copper-base, an initial flash of copper is deposited from a cyanide bath. The deposit is subsequently built up to a thickness of about 0.005 in. in an acid copper sulphate bath or Watts nickel bath, depending on the hardness of the sample. The bath compositions and plating conditions are given in Table I.

#### Polishing and Etching

*General.*—A method of polishing has been developed which, with slight modifications, is suitable for all types

\* Formerly at the Tin Research Institute, now at Battersea College of Technology.

† Supplied by North Hill Plastics, Ltd., Stoke Newington High Street, London, N. 16.





Fig. 1.—Pure tin showing recrystallisation and twinning due to adventitious working during polishing. Etched in alcoholic ferric chloride.  $\times 100$

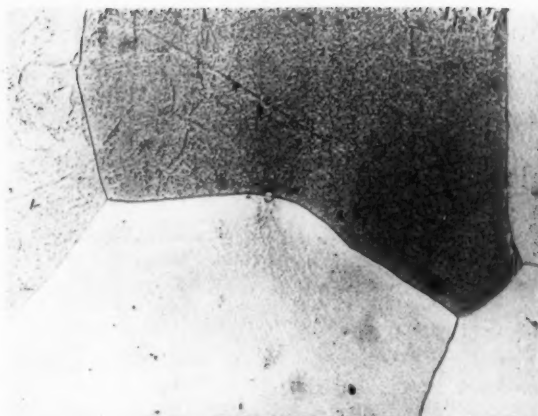


Fig. 2.—Pure tin polished carefully to avoid deformation. Etched in 2% hydrochloric acid in alcohol.  $\times 100$

of tin and tin alloys. The method was developed primarily for the tin-rich alloys which are the most difficult to polish.

The specimen is flattened on a file and ground on wet silicon carbide papers, using in succession the grades 180, 280, 320, 400 and 600. The papers are kept wet by a continuous stream of water which washes away particles of metal as they are cut from the surface of the specimen. This prevents clogging of the paper and ensures that the specimen is cut away with the minimum of surface work-hardening.

The greater part of the fine polishing is carried out with different grades of diamond dust compound. Although the initial outlay for diamond compound is high compared with that for the more conventional polishing materials, it has been found that, if used carefully, the diamond compound is more economical because of its durability. Every effort is made to ensure that the polishing wheels and pads used for diamond compounds are kept free from dust. It is essential to keep them well away from any coarse grinding operations, and from corrosive fumes. At the Tin Research Institute, all the diamond compound polishing apparatus is kept

in a separate dust-tight compartment, and, in addition, the individual wheels and pads are enclosed in glass cases. By taking these precautions, the useful life of the diamond compound is prolonged and the overall cost of polishing reduced.

The scratches from the 600 grade silicon carbide papers are removed by polishing on a Buehler Micro-cloth\* wheel impregnated with  $6\mu$  diamond compound. Having removed the 600 paper scratches, the specimen is polished on a second Micro-cloth wheel impregnated with  $1\mu$  diamond compound. Hand-polishing with  $\frac{1}{4}\mu$  diamond on a Micro-cloth pad completes the diamond polishing stage. In all cases a solution consisting of 10% trichlorethylene in filtered white spirit is used for lubrication. Final polishing is by hand on a Selvyt pad impregnated with  $\gamma$ -alumina, using distilled water for lubrication.

For most purposes Micro-cloth has been found most suitable for diamond compounds, since it has the nap necessary to hold the diamond, together with durability. The use of cheaper cloths is a false economy, since they generally wear out before the diamond compound has completed its useful life.

For the present paper, tin and tin alloys may be conveniently divided into three main groups, namely:

- (1) Tin and tin-base alloys.
- (2) Tin bronzes.
- (3) Aluminium-tin bearing alloys.

#### *Tin and Tin-Base Alloys*

Distortion of the surface layers of tin-rich alloys may cause recrystallisation, resulting in the true structure being masked. Fig. 1 shows the microstructure of pure tin which has been worked during polishing.

Considerable twinning and some recrystallisation has occurred. One of the original grain boundaries can be seen; this appears to have nucleated several new grains which are growing into the twinned matrix. Fig. 2 shows the structure of tin when prepared without deformation.

With tin-rich alloys that are in a meta-stable state, distortion of the surface regions as a result of working



Fig. 3.—B.N.F.M.R.A. type automatic polishing wheel used for diamond polishing.

\* This material and Met-cloth referred to later, are both obtainable from Shandon Scientific Co., Ltd., 6, Cromwell Place, London, S.W.7.



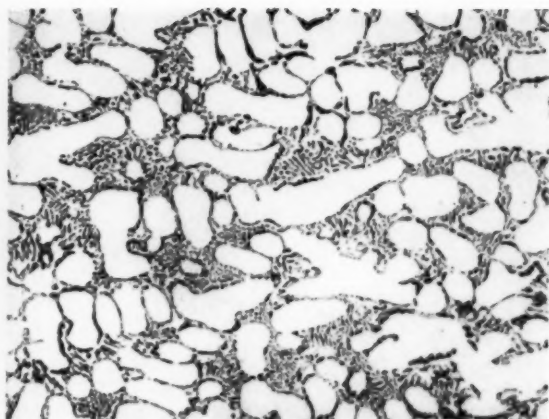


Fig. 4.—70% tin, 30% lead alloy, as-cast. Etched in glycerine/acetic acid.  $\times 75$

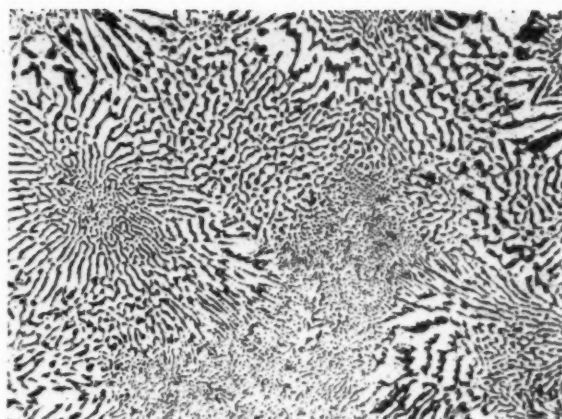


Fig. 5.—63% tin, 37% lead alloy, as-cast. Etched in glycerine/acetic acid.  $\times 75$

may cause structural changes to occur, e.g. precipitation from a supersaturated solid solution.

To avoid working of the surface regions, extreme care has to be taken during filing and grinding on the silicon carbide papers, since distortion extends to greater depth during the earlier stages of rough polishing. A fairly light pressure is preferred during all stages of polishing, and when the scratches from the previous stage have been removed, it is advisable to remove the same amount of metal again to eliminate any working due to previous stages.

It has been found with softer specimens that it is advisable to polish for a fairly long period (15–20 minutes) on the  $1\mu$  diamond wheel, to remove the residual traces of surface working before proceeding to the final stages of polishing. This can be carried out conveniently using the automatic polishing wheel developed by the British Non-Ferrous Metals Research Association and shown in Fig. 3.

When polishing on the two diamond wheels has been completed, the specimen is hand-polished on Micro-cloth

impregnated with  $\frac{1}{4}\mu$  diamond compound. The final polish is obtained by hand-polishing for about 30 seconds on a Selvyt cloth impregnated with  $\gamma$ -alumina and lubricated with water. The specimen is then ready for etching.

Though the method of polishing is the same for all types of tin and tin-base alloys, the etching reagents used for the various alloys are different. Pure tin etches without difficulty in either 2% hydrochloric acid in alcohol, or in an alcoholic acid ferric chloride solution, details of which are given in Table II.

The tin-lead alloys have simple two-phase structures, a eutectic occurring at 63% tin. Primary tin or primary lead phases are respectively present in hyper- and hypoeutectic alloys. Alloys containing primary tin are best etched in a reagent consisting of 1 part nitric acid + 1 part acetic acid + 8 parts glycerine, while a 5% solution of silver nitrate in water is most suitable for alloys containing the primary lead phase. Both reagents blacken the lead without attacking the tin. Figs. 4, 5 and 6 illustrate the use of these etchants on tin-lead alloys of various compositions.

Alloys containing antimony are a little more difficult

TABLE II.—ETCHING REAGENTS FOR TIN AND TIN ALLOYS

Reagent	Uses
Alcoholic Ferric Chloride : HCl 5 ml. $\text{FeCl}_3$ 2 gm. $\text{H}_2\text{O}$ 30 ml. Absolute alcohol 60 ml.	Can be used for tin and tin alloys. Recommended for etching grain boundaries in tin bronzes.
2% Hydrochloric Acid in Alcohol	Grain boundary etch for pure tin. Also useful for outlining tin particles in aluminium-tin alloys.
2% Nitric Acid in Alcohol	Recommended for etching whitemetal; it darkens the tin-rich matrix leaving the intermetallic compounds unattacked. Also recommended for outlining the tin particles in aluminium-tin alloys.
Glycerine Acetic Acid : $\text{HNO}_3$ 10 ml. Acetic acid 10 ml. Glycerine 80 ml.	Darkens the lead in the eutectic of tin-rich tin-lead alloys.
5% Ammonium Persulphate	Can be used to etch tin and tin-base alloys.
5% Silver Nitrate in Water	Darkens primary and eutectic lead in lead-rich tin-lead alloys.
Dichromate-Sulphuric Mixture : $\text{Na}_2\text{Cr}_2\text{O}_7$ 2 gm. $\text{H}_2\text{SO}_4$ 8 ml. Sat. $\text{NaCl}$ 4 ml. Water to make 500 ml.	Recommended for tin bronzes to reveal coring in $\alpha$ -solid solution and to etch up the $\delta$ -phase in the ( $\alpha$ + $\delta$ )-eutectoid.
Cupric Ammonium Chloride Solution	For polish attack on bronzes.

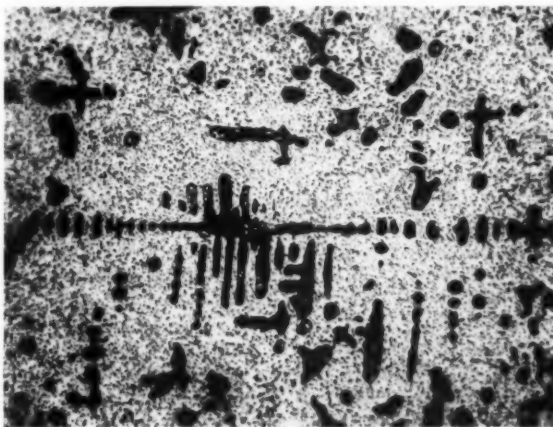


Fig. 6.—50% tin, 50% lead alloy, as-cast. Etched in 5% silver nitrate solution.  $\times 75$

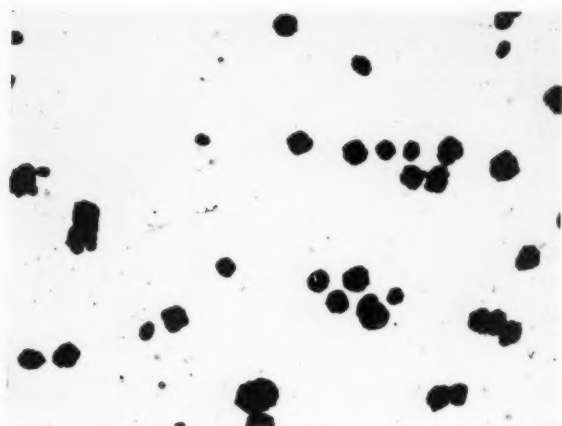


Fig. 7.—7.5% antimony, 92.5% tin alloy, showing pitting attack as result of standing before etching. Etched in 2% nital.  $\times 150$

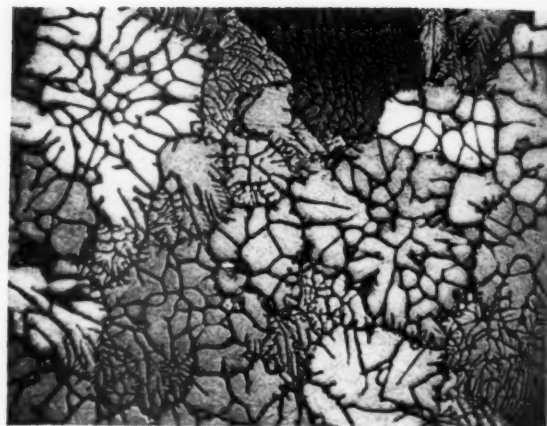


Fig. 8.—Same specimen as in Fig. 7, as-cast. Etched in 2% nital immediately after polishing.  $\times 100$

to etch than other tin-base alloys. Several of the etchants shown in Table II can be used, but 2% nitric acid in alcohol is considered best. Etching should be carried out as soon as possible after final polishing, since a thin porous film appears to form on the surface if the specimen is left standing. This results in pitting when the specimen is immersed in the etching reagent. Fig 7 shows this pitting attack on a chill cast 7.5% antimony + 92.5% tin alloy etched in 2% nital about 10 minutes after polishing. Fig. 8 shows the structure of the same alloy when etched in 2% nital immediately after polishing. The vein-like structure running through the grains is coring.

Figs. 9 and 10 show alloys containing respectively 7% antimony with 3% copper, and 14% antimony with 3% copper. In the first alloy, the cored solid solution has the compound  $\text{Cu}_6\text{Sn}_5$  embedded in it, and in the other the compounds  $\text{Cu}_3\text{Sn}_2$  and  $\text{SbSn}$ .

In alloys such as these, the tin-antimony solid solution is supersaturated at room temperature and therefore meta-stable. If strain energy remains in the surface regions as a result of working during polishing operations,

recrystallisation and precipitation may occur, giving a misleading structure. With all whitened metals, considerable care has to be taken both during polishing and etching if satisfactory results are to be obtained.

#### *Tin Bronzes*

This group is the easiest of the tin alloys to prepare for microscopic examination. Their greater hardness makes it easier to obtain a surface free from working and scratches, while their higher re-crystallisation temperature and greater stability preclude the spontaneous recrystallisation and precipitation found in the tin-rich alloys. The method of flattening the specimen on the file and grinding on the silicon carbide papers is the same as previously described.

Polishing can be carried out using any of the conventional polishing media, such as alumina, Bluebell, Silvo, etc. However, a more satisfactory polish can be obtained in a shorter time using diamond compound. It is considered that there is also less likelihood of removing inclusions and soft particles from the specimen with this technique. This is particularly important in

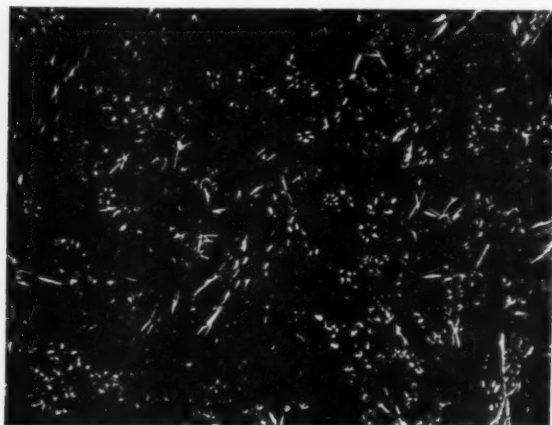


Fig. 9.—7.5% antimony, 3% copper, 89.5% tin alloy, as-cast. Etched in 2% nital.  $\times 150$

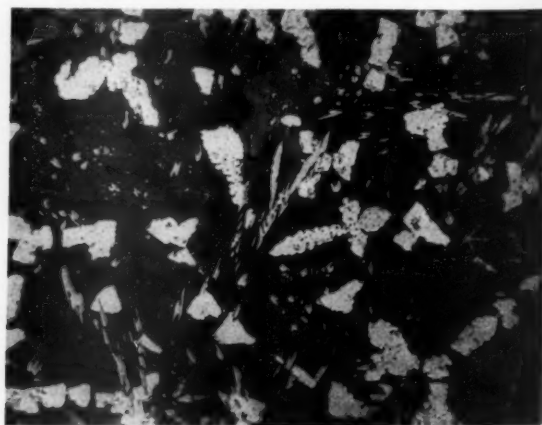


Fig. 10.—14% antimony, 3% copper, 83% tin alloy, as-cast. Etched in 2% nital.  $\times 150$



Fig. 11.—5% tin bronze, as-cast. Excessive attack during polish attack using cupric ammonium chloride.  $\times 150$

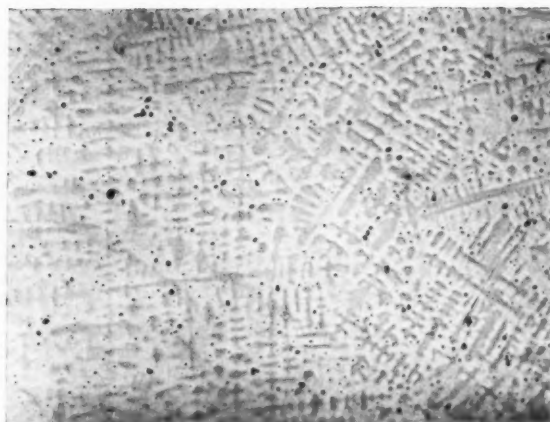


Fig. 12.—As Fig. 11, but with correct degree of attack during polish attack with cupric ammonium chloride and etching in sodium dichromate solution.  $\times 100$

the case of leaded tin bronzes, which contain soft lead particles in a hard matrix. After grinding on the papers, the specimen is polished on a Buchler Met-cloth wheel impregnated with  $6\mu$  diamond compound. Met-cloth, unlike Micro-cloth, is napless, and is used because it allows the diamond to cut faster and hence remove the scratches more quickly. Met-cloth is not suitable for tin and tin-base alloys because it is more likely to work the surface regions.

The specimen is polished on a Micro-cloth wheel impregnated with  $1\mu$  diamond compound. The last stage in diamond polishing is carried out by hand on Micro-cloth impregnated with  $\frac{1}{2}\mu$  diamond compound. The final polish is obtained by hand-polishing on a Selvyt cloth impregnated with fine  $\gamma$ -alumina, using water for lubrication. Except in the case of bronzes containing lead, a polish attack technique is used at this stage. A few drops of a saturated solution of cupric ammonium chloride are added to the polishing pad immediately before commencing the final polish. The cupric ammonium chloride solution is prepared by adding 0.880 g. ammonia to an aqueous 10% cupric chloride solution,

until the precipitate which forms initially is just redissolved. The specimen is then lightly rubbed on this pad for about 20–30 seconds and then washed with a jet of water and dried. If too much of this solution is applied to the polishing pad the specimen will become etched. A peculiarity of the etching occurring during this kind of polish attack is that any coring in  $\alpha$ -bronze is over-emphasised, giving the appearance of two phases. Fig. 11 shows this effect in an as-cast 5% tin bronze. If the correct amount of cupric ammonium chloride solution is used a scratch-free, polished surface is obtained.

As previously mentioned, leaded tin bronzes have to be polished with care to prevent removal of the soft particles of lead. The use of a napless cloth for the  $6\mu$  diamond wheel is particularly helpful in effecting this. Excessive pressure should be avoided at all stages, especially during polishing on the wheels. Final polishing is carried out on a Selvyt cloth impregnated with  $\gamma$ -alumina. Industrial spirit is used for lubrication since water may stain the lead particles. The polish attack reagent is not applied to the pad because it blackens the lead inclusions.

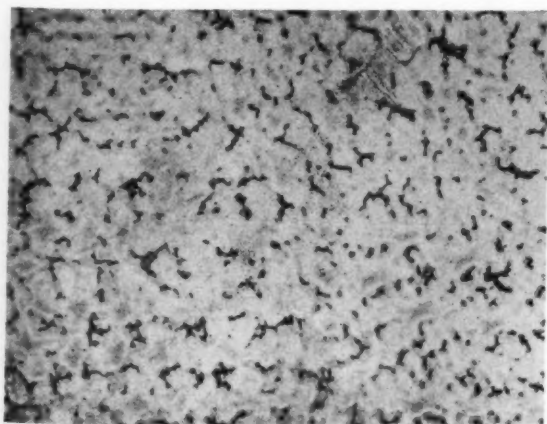


Fig. 13.—10% tin bronze, as-cast. Etched in sodium dichromate solution.  $\times 150$

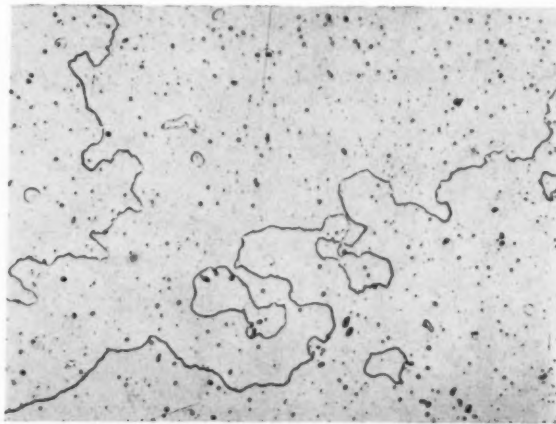


Fig. 14.—As Fig. 13, but annealed for 6 hours at  $650^{\circ}\text{C}$ . Etched in alcoholic ferric chloride.  $\times 150$





Fig. 15.—10% tin, 0.5% phosphorus bronze, as-cast. Etched by polish attack with cupric ammonium chloride.  $\times 1750$

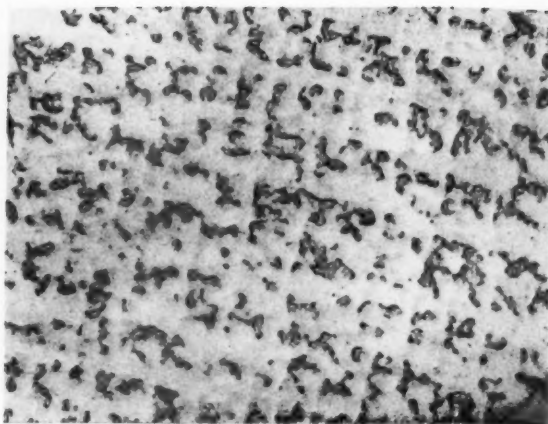


Fig. 16.—Phosphor bronze, as-cast. Etched in sodium dichromate solution.  $\times 150$

Tin bronzes are generally fairly easy to etch and there are a number of etchants available (see Table II). The dichromate-sulphuric mixture is most suitable for revealing coring in single-phased bronze and for etching the  $\delta$ -phase, but for revealing grain boundaries, an alcoholic acid ferric chloride solution is better.

Fig. 12 shows the microstructure of the bronze shown in Fig. 11, after polishing with the correct amount of polish attack reagent on the Selvyt pad, and subsequent etching in sodium dichromate solution. It consists of cored  $\alpha$ -solid-solution with some fine gas porosity distributed interdendritically. The true nature of the coring of the solid solution is revealed by the sodium-dichromate etch.

Fig. 13 shows the microstructure of an as-cast 10% tin bronze etched in sodium dichromate solution. It consists of ( $\alpha + \delta$ )-eutectoid distributed interdendritically, in a cored  $\alpha$ -solid-solution matrix. Fig. 14 shows the microstructure of the same bronze after annealing at 650° C. for 6 hours. It was etched in alcoholic ferric chloride solution to reveal the grain boundaries. All coring has been removed and the  $\delta$ -phase has been taken

into solid solution, resulting solely in irregularly shaped grains of  $\alpha$ -solid-solution. Some evenly distributed fine porosity is evident.

In the true phosphor bronzes the phosphorus content exceeds the limit of solid solubility at room temperature, and the excess precipitates out as the compound  $\text{Cu}_3\text{P}$ . Depending on the tin content, the phosphide may exist as isolated particles in an  $\alpha$ -bronze matrix, or as complex phase in association with  $\alpha$  and  $\delta$ . In the unetched condition,  $\text{Cu}_3\text{P}$  appears blue-grey and the  $\delta$ -phase a light blue colour, making it difficult to distinguish between them. If final polishing is carried out using the polish attack technique with cupric ammonium chloride, the  $\text{Cu}_3\text{P}$  is slightly darkened, thus distinguishing it from the  $\delta$ -phase. Fig. 15 shows the microstructure of the binary complex ( $\alpha + \text{Cu}_3\text{P}$ ) associated with ( $\alpha + \delta$ )

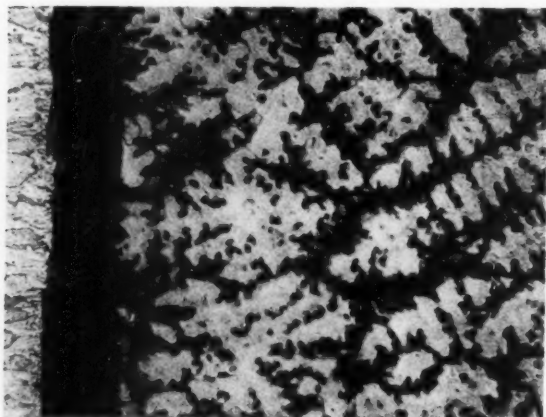


Fig. 17.—Tin sweat layer on phosphor bronze. Etched in sodium dichromate solution.  $\times 150$



Fig. 18.—As Fig. 17. Etched by polish attack with cupric ammonium chloride.  $\times 750$



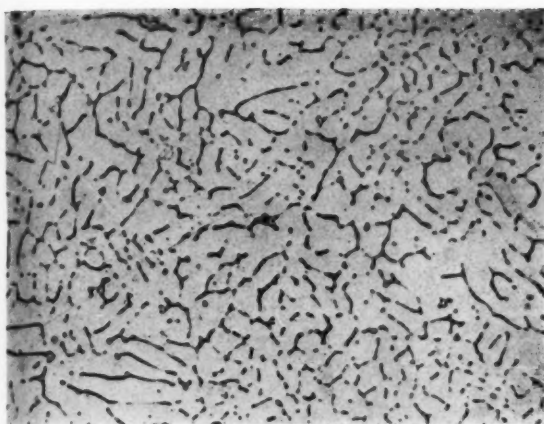


Fig. 19.—20% tin, 1% copper, 79% aluminium alloy, as-cast. Etched in 2% nital.

× 150

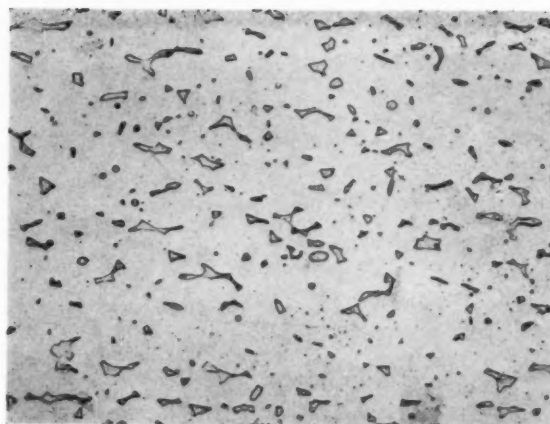


Fig. 20.—20% tin, 1% copper, 79% aluminium alloy, cold-rolled and annealed 1 hour at 350° C. Etched in 2% nital.

× 150

eutectoid in a phosphor-bronze containing 10% tin and 0.5% phosphorus, as revealed by the polish attack method. For examination at low magnification, the polish attack is followed by etching in sodium dichromate solution, to reveal the coring in the primary  $\alpha$ -phase and the distribution of the eutectoid and the complex phases (see Fig. 16).

Tin bronzes are harder than the plastic mounting medium, and consequently bevel during polishing. Therefore, when it is necessary to examine the edges it is necessary to electrodeposit a supporting layer of copper. Figs. 17 and 18 show the microstructure of a tin sweat layer on the surface of a phosphor bronze, the edge of which has been retained by a supporting layer of copper. The structure of the tin sweat layer consists mainly of  $(\alpha + \delta)$ -eutectoid, together with a little primary  $\delta$ -phase. An interesting feature is the line of  $\text{Cu}_3\text{P}$  which outlines the interface between tin sweat layer and bronze (Fig. 18). This is unusual, since the  $\text{Cu}_3\text{P}$  usually sweats out on to the surface as an  $(\alpha + \text{Cu}_3\text{P})$ -complex in conjunction with the  $(\alpha + \delta)$ -eutectoid.

The structure as shown by Fig. 17 was revealed by a light polish attack with cupric ammonium chloride, followed by etching in sodium dichromate solution. For examination at higher magnifications, only a light polish attack is necessary (see Fig. 18).

#### Aluminium-Tin Alloys

Aluminium-tin alloys of the composition used for bearings are softer than tin-bronzes, and it is consequently more difficult to obtain a scratch-free surface. These alloys generally contain at least 20% tin, together with 1% copper to harden the aluminium matrix. The microstructure consists of a discrete tin phase in a matrix of aluminium-copper solid solution. Grinding prior to diamond polishing is carried out on emery papers lubricated with paraffin, finishing on a 0000 or equivalent grade. The 0000 emery scratches are removed on a Met-cloth wheel impregnated with 6  $\mu$  diamond compound. Use of this cloth minimises removal of soft tin particles from the matrix. Final polishing is similar to the technique for tin-rich alloys, using the minimum of pressure when hand-polishing with the  $\gamma$ -alumina.

Echants suitable for aluminium-tin alloys are 2%

hydrochloric acid in alcohol and 2% nitric acid in alcohol. Both outline the areas of tin, leaving the matrix un-attacked. Fig. 19 shows the microstructure of an alloy containing 20% tin and 1% copper in the cast condition etched for a few seconds in 2% nitric acid in alcohol. It consists of a network of tin in an aluminium-copper solid solution matrix. Fig. 20 shows the microstructure of the same alloy after cold-rolling and annealing, the tin particles now being distributed at random. Higher copper contents reduce the tendency for the continuous network of tin to form on casting. Fig. 21 shows the microstructure of an alloy containing 20% tin + 3% copper in the cast condition. The tin particles are rounded and distributed at random in the matrix.

Since aluminium-tin alloys are fairly soft, relatively little bevelling occurs at the edge of the specimen. It is therefore not necessary to electrodeposit a supporting layer, when requiring to examine the surface regions. Fig. 22 shows a section through the surface of a 50% tin alloy in the cast condition.

#### Electrolytic Polishing

The merits of electrolytic polishing are that it is quicker than mechanical polishing and that there is less risk of obtaining false structures due to twinning and recrystallisation. With tin and its alloys, electrolytic polishing is restricted to the pure metal, some single-phase alloys and binary tin-lead alloys. However, it has been found that a higher quality polish can be obtained on these materials using mechanical methods, if sufficient care is taken. For routine examination of a large number of specimens of one type of alloy, it is possible that the greater speed of electrolytic polishing might be advantageous. Electrolytic polishing is also useful when examining tin alloys for grain size, since there is little chance of obtaining a false microstructure.

Suitable electrolytic polishing solutions and conditions for polishing are given in Table III. Most of these have been tried in the laboratory and have been found satisfactory within the limits outlined above.

#### Tin and Tin Alloy Coatings

##### General

A large proportion of the world's tin is used in the form of coatings, as for example, in hot-dipped and

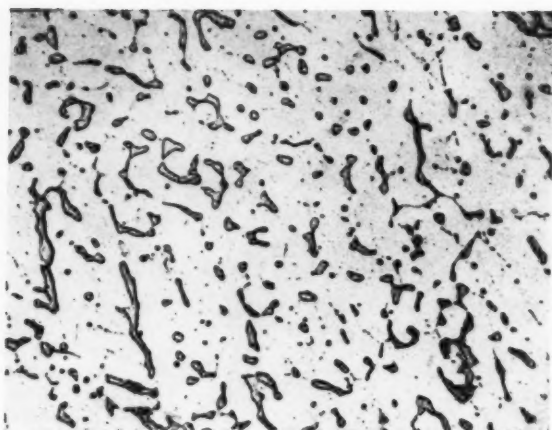


Fig. 21.—20% tin, 3% copper, 77% aluminium alloy, as-cast. Etched in 2% hydrochloric acid in alcohol.  $\times 250$

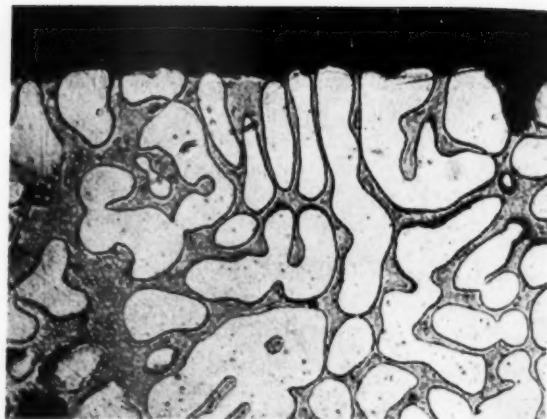


Fig. 22.—50% tin, 50% aluminium alloy. Etched in 2% nital.  $\times 500$

electro-tinplate, and as electrodeposited tin or alloy coatings on fabricated articles. Considerable quantities are also used in the manufacture of bearing metals, which are generally backed by steel or copper-base alloys.

In all cases when coatings of tin or tin alloys are on a harder basis metal, considerable difficulty is encountered, when preparing them for micro-examination, in preventing a "step" forming at the interface between the relatively soft coating and the basis metal. With thin coatings it is advantageous to electrodeposit a supporting layer, on top of the coating, of similar hardness to the basis metal. When the basis is copper or a copper alloy the supporting layer should be copper, while nickel is used for coatings on steel or cast iron. Details of the plating solutions were given in Table I. A flash of copper is preferably applied from the cyanide bath before plating nickel or copper on to tin coatings. With the thicker layers of, for example, bearing metals, there is no advantage to be gained from a supporting layer, except when it is required to examine the edges of the layer.

An additional difficulty with tin and tin-base alloy coatings, is that diffusion can occur in them at, or very little above, room temperature. Thus if an accurate

value of the thickness of any alloy or diffusion layer directly present at the interface is required, precautions have to be taken during mounting, polishing and etching to keep the specimen at room temperature and to examine with the minimum of delay.

#### Mounting

For these reasons it is desirable that samples with tin and tin-base alloy coatings are mounted at room temperature. The N.H.P. mounting material has been found most suitable for this, and is used for all specimens, irrespective of whether the coating is liable to alloy with the basis metal or not. External pressure is generally used since it gives a non-porous mount, but in the case of thin sheet specimens which may buckle easily, mounting should be carried out without pressure.

Specimens are generally mounted so that a normal cross-section of the coating is obtained. However, when examining very thin coatings, as for example, electro-tinplate, oblique specimens, or so-called taper-sections, are often used.<sup>10, 11</sup> This has the effect of increasing the effective magnification in the direction normal to the interface, and so facilitating study (see Fig. 23).

The linear enlargement is termed the distortion ratio,

TABLE III.—ELECTROLYTIC POLISHING SOLUTIONS FOR TIN-BASE ALLOYS

Composition	Cathode	Voltage	Current Density (A./sq. dm.)	Time	Temperature (° C.)	Remarks
Perchloric Acid . . . . . 194 ml. Acetic Anhydride . . . . . 806 ml. (reference 3)	Tin	25-40	9-15	8-10 min.	Below 25° C.	Due to explosion risk, care should be taken that the temperature remains below 25° C. W. C. McG. Taggart <sup>4</sup> and P. A. Jacquet <sup>5</sup> have given detailed precautions for using these solutions.
Perchloric Acid (sp. gr. 1.60) . . . . (reference 6)	Aluminium	50-60	40	10-15 sec.	Below 35° C.	Puttick claims that this electrolyte is safer than Jacquet's. <sup>3</sup> The face to be polished should be vertical and rotated at 50-100 r.p.m.
Perchloric Acid . . . . . 63 ml. Acetic Acid . . . . . 300 ml. Distilled Water . . . . . 12 ml. (reference 7)	Tin	20-30	9-15	10 min.	25	The anode should be vertical and the electrolyte agitated. Explosion risk is also present with this solution.
Ethyl Alcohol . . . . . 144 ml. Aluminium Chloride (anhydrous) . . 10 g. Zinc Chloride (anhydrous) . . . . 45 g. Water . . . . . 32 ml. Butyl-Alcohol . . . . . 16 ml. (reference 8)	Tin or stainless steel	25-30	30	Periods of 1 min.	20	The dark layer formed on the specimen is removed by a jet of hot water after each cycle. The cycle is repeated 4 or 5 times before polishing is complete.
Commercial Grade Fluoboric Acid containing 2% Sulphuric Acid . . . . . (reference 9)	Stainless steel	15-21	400-700	3-5 sec.	20-45	Can be used for tin-lead alloys, current density varying according to the composition. To avoid etching, a specially designed cell is used.

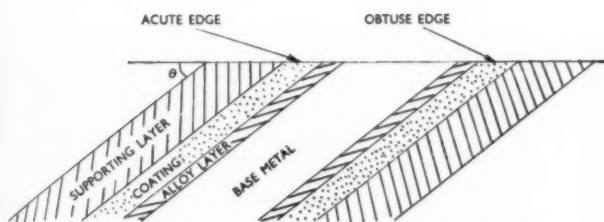


Fig. 23.—Components in a taper section of tinplate.

and is equal to the cosecant of the angle between the section plane and the specimen axis. Thus, for the distortion ratio of 10, which is commonly employed, the angle is  $5^{\circ} 43'$ .

Oblique sections are mounted using a special plug in the mounting die, which has the mounting face at the required angle  $\theta$  as shown in Fig. 24a. The specimen is placed in the die with the coated surface downwards and mounted in the normal way, using external pressure. The specimen is then extracted, and the plug is replaced by one with its mounting surface normal to the axis of the die. The mounted specimen is then inverted and returned to the die with sufficient mounting compound to cover it completely. The further layer of compound is allowed to set and welds on to the original mount (see Fig. 24b). When the specimen is extracted from the die, the surface is covered by a layer of mounting compound which has to be removed before grinding the specimen (see Fig. 24c). This should be done by machining to ensure that the surface of the mount remains at the correct angle to the specimen. It is important that the specimen should not be machined, as there is a danger of tearing it from the mount. Experience has shown that a true structure is only obtained along the acute edge (see Fig. 23).

#### Polishing and Etching

When polishing tin and tin alloy coatings, the effect of difference in hardness between the coating and the basis metal can be sufficiently minimised, by the use of special techniques, to allow satisfactory examination of the interface.

The specimens are flattened on a file, and ground on successively finer grades of silicon carbide papers in running water. Grinding on successive papers is carried out alternately in the directions shown in Fig. 25.

It has been found that the longer the time spent at any stage during preparation the more likely is a step to form. This is particularly the case when the final stages are reached, and thus a firm pressure is required during both grinding on the papers and during diamond polishing, to reduce to a minimum the time required at any one stage.

To obtain satisfactory results it is essential to carry out the final stages of polishing with diamond compounds. Polishing with the conventional polishing media, such as Bluebell, Silvo, alumina, etc., results in the formation of a considerable step which makes examination of the interface difficult. When using diamond compounds, precautions still have to be taken to keep the step to a minimum. A firm pressure on the  $6\mu$  and  $1\mu$  polishing wheel is necessary, and the interface should never be at right angles to the direction of polishing.

The specimen is polished on a Met-cloth wheel impregnated with  $6\mu$  diamond compound to remove the

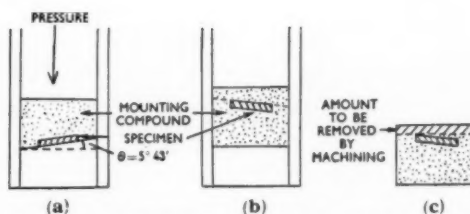


Fig. 24.—Method of mounting a taper section: (a) mounting plug with mounting surface at  $5^{\circ} 43'$  to the horizontal; (b) mounting plug with mounting surface parallel to horizontal; (c) mounted specimen as extracted from the die.

scratches from the finest paper. This napless cloth is used because it allows fast and equal cutting of the coating and basis metal, thus limiting the depth of any step formed. The specimen is then polished on Micro-cloth with  $1\mu$  diamond compound for a short period (generally less than 60 seconds). Final diamond polishing is carried out on Micro-cloth impregnated with  $\frac{1}{2}\mu$  diamond compound. A final polish is obtained by lightly rubbing on a Selvyt cloth impregnated with  $\gamma$ -alumina for about 20–30 seconds. Water is used for lubrication, but industrial spirit is a useful alternative, particularly if staining is liable to occur.

No mention has yet been made of the polishing of the harder tin alloy coatings such as speculum and tin-nickel. These alloys are electrodeposited, generally on to steel or copper-base alloys, to give corrosion resistance, and to enhance appearance. Because of their hardness there is no danger of a step being formed at the interface. Such specimens may be satisfactorily polished using the same method as for bronzes.

When examining tin and tin alloy coatings, it is often the interface between coating and basis metal which is of primary interest, and etching is therefore usually carried out with the object of revealing the microstructure at the interface. Hot-dipped and electrodeposited tin coatings on steel are best etched in a 5% alcoholic picric acid solution. Besides revealing the microstructure of the steel, this reagent outlines the interface between steel and tin-iron alloy layer without etching the tin. Romig and Rowland<sup>12</sup> have described a double etching technique for revealing this layer, consisting of 1 drop nitric acid (conc.) + 2 drops hydrofluoric acid + 25 ml. glycerine for outlining the interface between tin and  $\text{FeSn}_2$ , followed by etching in 5% picric acid to outline the steel- $\text{FeSn}_2$  junction. In the author's experience the interface between tin and  $\text{FeSn}_2$  is easily distinguished without etching. Fig. 26 shows the microstructure at the inter-

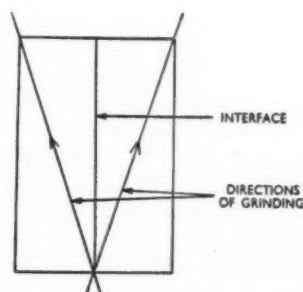


Fig. 25.—Grinding direction for specimens with soft coatings.



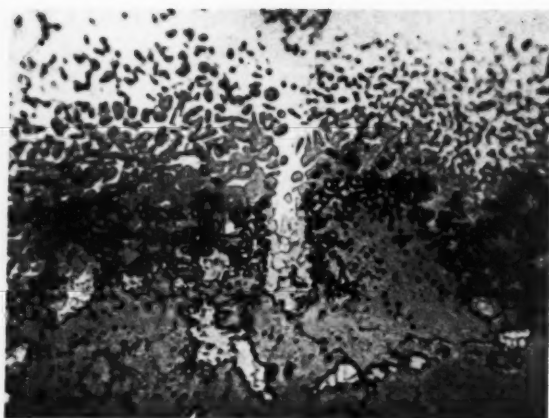


Fig. 26.—Taper section on hot-dipped tinplate. Distortion ratio 10 : 1. Etched in 5% alcoholic picric acid solution.  $\times 1500$

face of a hot-dipped coating on steel as revealed in an oblique section. The etch has outlined the interface between the steel and  $\text{FeSn}_2$ . The interface between  $\text{FeSn}_2$  and tin is easily distinguished without further etching.

Fig. 27 shows the microstructure of a hot-dipped tin coating on steel prepared as a normal cross-section. The etch has again outlined the interface between the steel and the  $\text{FeSn}_2$  layer. In the field shown, there are some particles of steel in the tin coating completely enclosed by alloy layer; parts of the nickel supporting layer can also be seen. In Figs. 26 and 27 it can be seen that, although a small step has formed, the microstructure at the interface is still quite clear.

Tin coatings on cast iron are also etched in alcoholic picric acid. The reagent etches the basis metal without attacking the tin. Fig. 28 shows the microstructure of a hot-dipped tin coating on grey cast-iron. The microstructure of the cast iron consists of graphite flakes in a pearlitic matrix. Due to the presence of cementite, the picric acid etch has not outlined the interface between the iron and the  $\text{FeSn}_2$  layer, as it does with tin coatings

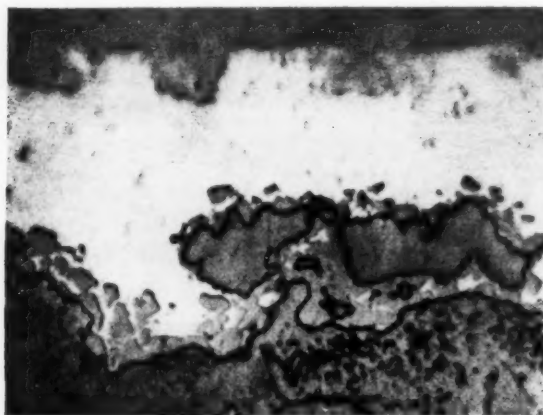


Fig. 27.—Hot-dipped coating on steel. Etched in 5% alcoholic picric acid solution.  $\times 2200$

on ferritic steels, however, the  $\text{FeSn}_2$  layer is still easily distinguished. In the field shown, a flake of graphite has extended to the surface of the cast iron, and the alloy layer and tin coating have bridged over it.

Electrodeposited or hot-dipped tin coatings on copper and copper-base alloys are etched in dilute ammonium hydroxide with a few drops of hydrogen peroxide added. This reagent etches the basis metal and outlines the interface with the alloy layer, without attacking the tin. Fig. 29 shows the microstructure of a hot-dipped tin coating on copper. The interface between the copper and alloy layer, in this case  $\text{Cu}_6\text{Sn}_5$ , is clearly outlined. As with tin coatings on steel, the interface between alloy layer and tin can be clearly distinguished without further etching. In the field shown, part of the copper supporting layer can be seen.

Steel-backed whitemetal bearings are best etched in 2% nitric acid in alcohol. This reagent generally etches both the steel and the whitemetal. With some specimens, however, the microstructure of the whitemetal is revealed before that of the steel. In such a case, the specimen should be given a second etch in 5% picric acid, which etches the steel alone without affecting the white metal.

Etching in 2% nitric acid in alcohol should be carried out immediately after final polishing is completed. If the specimen is left standing and is then etched in this reagent, the whitemetal develops pits instead of etching evenly. This phenomenon was discussed in the earlier section on tin-antimony alloys. Fig. 30 shows the microstructure of a steel-backed whitemetal bearing which has been etched in 2% nitric acid in alcohol only. The structure of the steel adjacent to the interface is distorted as a result of machining prior to tinning and lining with whitemetal. It is suggested that on account of this distortion, the highly reactive steel surface caused rapid nucleation and growth of the alloy layer during tinning and lining. This probably explains why the alloy layer is in the form of columnar crystals, instead of being a continuous layer similar to those shown by Figs. 27 and 28. Crystals of  $\text{SbSn}$  and  $\text{Cu}_6\text{Sn}_5$  appear to have precipitated onto the needles of  $\text{FeSn}_2$ .

Due to the thickness of the whitemetal coating, there is no advantage to be gained by electrodepositing a

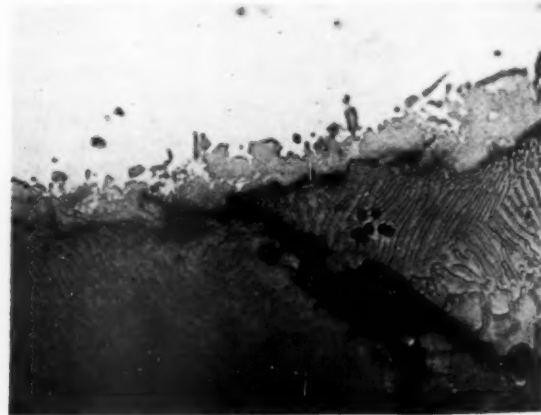


Fig. 28.—Hot-dipped coating on grey cast iron. Etched in 5% alcoholic picric acid solution.  $\times 1500$

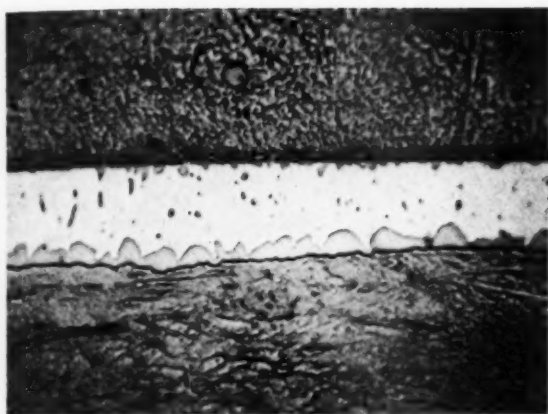


Fig. 29.—Hot-dipped coating on copper. Etched in dilute ammonium hydroxide and hydrogen peroxide.  $\times 1500$

supporting layer on to it. Therefore, the step formed during polishing is greater than is obtained with a thin coating edge-supported by a layer of copper or nickel. Even so, the microstructure at the interface can be easily discerned.

Steel-backed aluminium-tin bearings are produced by rolling the aluminium-tin bearing alloy on to aluminiumised steel. Subsequent annealing at  $350^{\circ}\text{C}$ . for 1 hour is carried out to soften the aluminium-tin alloy.<sup>13</sup> When the bearing is finished the aluminium-tin alloy is in the softened condition and the steel is still in the hard-rolled condition. The difference in hardness between coating and basis metal, therefore, is of the same order as in steel-backed whitmetal bearings, and the same precautions should be taken during polishing to minimise the step formed at the interface.

Steel-backed aluminium-tin bearings are etched in 2% nitric acid in alcohol, which outlines the tin particles in the aluminium-tin alloy. It is then possible to distinguish the interface between the aluminium-tin and aluminium layers. The microstructure of the steel may or may not be etched in the time required to etch the aluminium-tin layer, but may be emphasised by subsequent etching as for steel-backed whitmetal bearings. The interface between steel and aluminium is easily discernible without the additional etch, as shown in Fig. 31.

### Summary

New methods and techniques for preparing tin and tin alloys for micro-examination have been developed at the Tin Research Institute with a view to eliminating the high degree of individual skill demanded by the older methods. The techniques are based on the use of successively finer grades of diamond compound for all but the final stage of polishing. Diamond compound appears to give the most satisfactory results and is also more economical than conventional abrasives, if used judiciously.

Pure tin and tin-rich alloys present difficulties as a result of their softness, and extreme care is used during polishing, a longer time than usual being spent at each stage. Where tin is a minor addition less difficulty is encountered. Tin and tin alloys presented as coatings on harder basis metals are the most difficult type of speci-

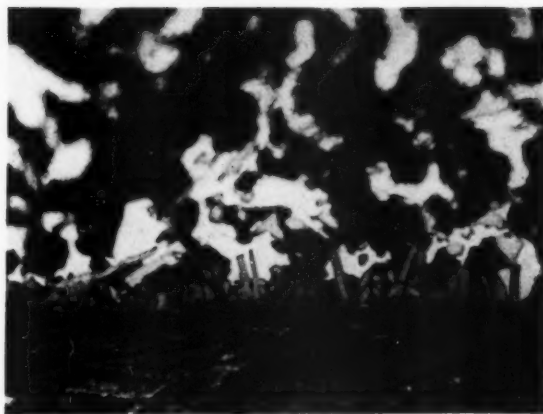


Fig. 30.—Steel-backed whitmetal bearing. Etched in 2% nital.  $\times 1500$

men to prepare. The difference in hardness between coating and basis metal may cause a step to form during polishing, which can be restricted sufficiently to allow a detailed examination at the interface, by the use of diamond compound which removes basis metal and coating equally. Suitable etching reagents for a range of tin-containing alloys have been described with the help of photomicrographs. Electrolytic polishing offers limited advantages for these materials and only in certain circumstances may be beneficially employed.

### Acknowledgments

This work was carried out in the laboratories of the Tin Research Institute and the author is indebted to the International Tin Research Council for permission to publish this paper. Thanks are also due to Dr. E. C. Ellwood and Mr. C. J. Thwaites for helpful discussions.

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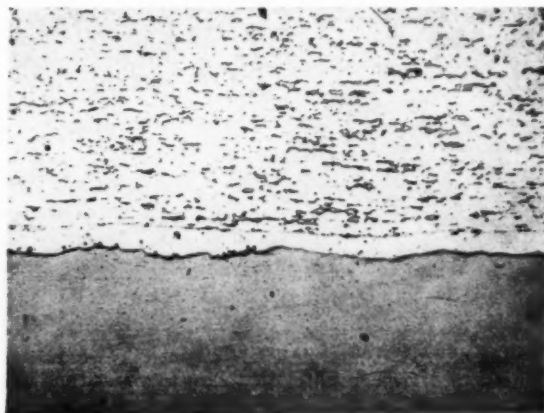


Fig. 31.—Steel-backed aluminium-tin bearing. Etched in 2% nital.  $\times 100$

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## Nickel Refining Film

THIRD in the Inco series of sound, colour films describing nickel production, "Refining Nickel from the Sudbury Ores" takes over the story at the point where the smelting operations have produced nickel oxide sinter. After a brief prologue, the nature of the Sudbury ore is explained and there is a quick resumé of the processes that led up to the production of the oxide sinter, which is the nickel refiner's starting material. The principle of electrolytic refining is demonstrated and the preliminary processes of melting the sinter, cleaning the slag, and casting the nickel anodes are shown. Then follows a much more detailed account of the theory of electrolytic refining, together with a description of the method used to purify the electrolyte, and so prevent metals other than nickel depositing on the cathode. The actual process of electrolytic refining is then shown. The sequences showing the purification of the electrolyte lead into a brief account of the electrolytic refining of cobalt. The recovery of the nickel from the special alloy containing precious metals, made during the smelting operation, is shown.

The Mond carbonyl process of refining nickel is described, first by a laboratory demonstration of the nickel carbonyl reaction and then by sequences that show the actual plant, together with animations to illustrate the way each unit operates. The pressure carbonyl process for the production of nickel powder is described in detail. Finally, the chemical treatment applied to the residue from the carbonyl refining is briefly illustrated to show how the copper, cobalt, and residual nickel contained therein are turned into useful chemical salts and oxides.

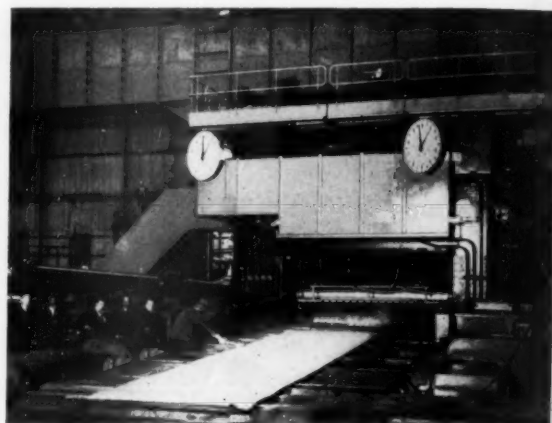
Two further films are in course of preparation, one dealing with the refining of copper and the other with the refining of precious metals. Together, the five films will have covered all the operations required to process the Sudbury ores, and will comprise a valuable source of information for students, technical societies and certain lay audiences.

The nickel refining film was produced for the International Nickel Co. of Canada, Ltd., by Film Graphics, Inc. New York. It runs for 52 minutes and is available on free loan on application to: The Publicity Department, The Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W.1.

## New Plate Mill in Commission

THE first slab was rolled recently in the new £500,000 steel plate rolling mill at the Scunthorpe works of Appleby-Frodingham Steel Co., a branch of The United Steel Cos., Ltd. This marks the completion of the first stage of a £6 million development scheme which will lead to a considerable increase in the output of steel plates for the ship-building and constructional engineering industries. Improved surface finish, closer rolling tolerances and more accurate gauge across the width of the plate are other features associated with the mill's higher production. Initially, it will produce about 9,000 tons per week.

The new Davy-United 12 ft. four-high mill replaces an



existing 10 ft. mill which was installed nearly thirty years ago. Powered by twin 4,000 h.p. D.C. motors of Metropolitan-Vickers design and construction, its two work rolls weigh 29 tons each and the back-up rolls 72 tons each—the heaviest rolls ever to be incorporated in a British rolling mill. Its entire operation is controlled by one man, working from a specially-designed pulpit, which is equipped with the latest type universal control system.

The mill is capable of rolling plates from  $\frac{1}{4}$  in. thick upwards. The maximum rolling width of from 11 ft. 4 in. to 11 ft. 6 in. can be used for plates  $\frac{1}{2}$  in. thick and upwards. Although the immediate effect of the installation will be to raise the company's plate output by several hundred tons per week, the full benefits of the scheme will not be realised until towards the end of next year. By that time, additional facilities will have been provided, including two new slab reheating furnaces, new cooling banks, mechanical shears, loading bay.

## Kent German Office

As a result of continued expansion in Europe, and in order to offer the German market the best possible service, George Kent, Ltd., announce that a Branch Office is in the process of being established at Krefeld in the heart of the industrial Ruhr. This latest addition to the Kent organisation will have both Commercial and Technical Sales Managers, and the skilled technical staff will be supported by a comprehensive service and spare-parts department covering the whole of the Kent range of products. The address of the office is George Kent, Ltd., Zweigniederlassung für Deutschland, Krefeld Westparkstrasse, 54 (Telephone: 25692; Telegrams: Kents Krefeld).

## Change of Address

THE administrative offices of Kelvin Hughes (Industrial), Ltd., have been moved from 2 Caxton Street, London, S.W.1., to their new building at Empire Way, Wembley, Middlesex (Telephone: WEMbley 8888; Telegrams: Kelhue, Wembley).



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